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Demonstration of a Closed Loop Reuse System in a Fiberglas Textile Plant

Owens-Corning Fiberglas Corp.
Toledo, OH

Prepared for

Industrial Environmental Research Lab.
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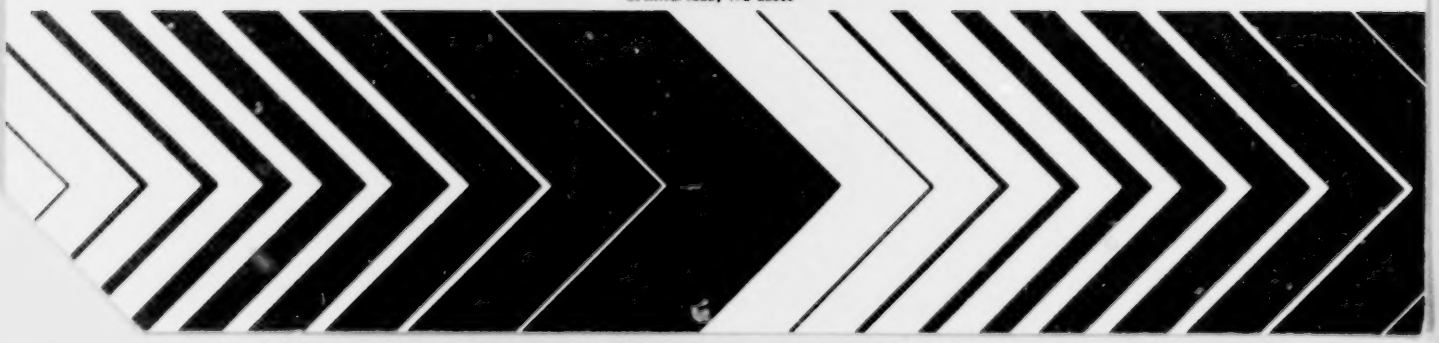

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16. ABSTRACT The report describes work done toward providing a totally recycled water system for Owens-Corning's textile fiber manufacturing plant at Anderson, SC. (The work was based on pre-1968 pilot plant work by Owens-Corning that resulted in development of totally recycled industrial wastewater systems for all of their insulation manufacturing plants.) Water quality requirements for the Anderson plant were considerably more stringent than for insulation manufacturing. Test and engineering design work started in 1973. Design work was completed in March 1977 and actual field work was started. All sanitary wastes from the plant were segregated for separate treatment. Much modification to the existing treatment was required to improve the quality of primary and secondary effluent for tertiary treatment. In the final process, biologically treated effluent is sand-filtered, followed by activated carbon adsorption and disinfection with chlorine. Major items of equipment added were a commercial upflow pressure sand filter and three upflow activated carbon columns with backwash capabilities. The quality of treated effluent is completely satisfactory for all plant operating requirements. Total recycle of treated effluent was realized in mid-1978 and has continued since then. Complete closed-loop operation had not yet been achieved. Discharge to Betsy Creek has been greatly reduced.

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Glass Fibers	Chlorine		11B	07B
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by

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ABSTRACT

In March 1973, Owens-Corning Fiberglas Corporation was awarded a U.S. EPA Demonstration Grant for the preliminary engineering of a closed loop industrial wastewater recirculation system for the fiberglass textile industry. This work was documented in U.S. EPA publication, Industrial Wastewater Recirculation System: Preliminary Engineering (1), in February, 1977. The report concluded that reclamation of the effluent from the existing wastewater treatment facilities followed by sand filtration, carbon adsorption, and disinfection would result in a product water suitable for reuse in process cooling water, air scrubbing, and washdown water systems.

Upon completion of the final design, construction of the treatment and reuse system began in March 1977 and was completed by March 1978. By August 1978, all recycle systems were on-line and the operation of the entire water reclamation and recycle system became a reality.

This report documents an evaluation of the full-scale system for the period January 1979 through October 1979. As the evaluation proceeded, numerous design and operational deficiencies were identified. Many of these were corrected by minor modifications while more complex modifications required additional pilot study and their impact upon the system was projected using transformed operational data. The impact of these modifications on attaining total system closure are presented in this report.

This report was submitted in fulfillment of Grant No. S801173 by Owens-Corning Fiberglas Corporation under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a period from March 1973 to December 31, 1979 and the report was completed as of March, 1980.

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CHAPTER I

INTRODUCTION

The Owens-Corning Fiberglas Corporation (OCF) in 1968 established an objective of total water recycle for all its manufacturing facilities. The technology of total recycle was successfully developed and demonstrated for fibrous glass insulation facilities in 1968 at the Corporation's Barrington, New Jersey plant (2). Following the success in that area, the Corporation set out to develop the technology of total recycle for textile fibrous glass facilities. After conducting the necessary background research, OCF submitted an application for federal funding.

In March, 1973, the Corporation was awarded an Environmental Protection Agency Demonstration Grant (S801173). Research and development work (Phase I) for the grant was conducted at the OCF manufacturing facility at Anderson, South Carolina. This work along with construction work under Phase II of the grant was originally to be completed over a three-year period. Research and development work delays, brought about by interruptions in manufacturing operations at the Anderson facility, required that the Phase I completion date be extended to July 1, 1976. The entire preliminary engineering work that was a result of Phase I was documented in Environmental Protection Agency Publication, Industrial Wastewater Recirculation System: Preliminary Engineering (1), in February 1977.

Upon completion of the final design, the construction phase, Phase II began in March, 1977 and was completed by March 1978. In April, 1978, all low quality recycle systems were apparently "de-bugged", and the low quality recycle system became operative. By August, 1978 all high quality recycle systems were apparently "de-bugged" and operation of the entire reclamation and recycle system became a reality.

Upon preliminary investigation of the entire operating system between August, 1978 through December, 1978, it was apparent that total system closure was not being achieved. During this period several supply system concepts were revised in the operating system to attempt system hydraulic balance and system closure. By December 1978, it was apparent that although these modifications did improve hydraulic balance, total system closure was not achieved; even though five months of operational experience had transpired with a wealth of gained operational knowledge. Thus, the most realistic method to determine all of the "hidden" problems within the system, was to investigate and document the entire system in a detailed and organized manner for an extended period of time. Simultaneously, grant schedule revisions required a 9-month evaluation of the full scale total recycle system to be completed by December 31, 1979. Hence, a detailed investigation of the entire system operation and final design began in January, 1979.

As the evaluation preceeded, numerous recycle and treatment system design and operational deficiencies were identified. Several minor modifications were conceived, installed, and evaluated during the study; while more complex modifications required that their impact upon the system be projected using transformed operational data. These latter proposed changes have also required additional pilot study and at this time appear feasible and consistent with the projected impacts contained in this report, (i.e.) successfull implementation will make major improvements in the system hydraulic balance which should allow system closure. However, as in any totally closed recycle system, fresh water inputs must be kept to the minimum amount used to establish the design. Any excess fresh water entering the system over the design level will accumulate within the system and most probably result in hydraulic imbalance and discharge. At this time fresh water control at the Anderson facility remains a variable which is difficult to assess. The facility is so large and its manufacturing operations so diverse, that numerous small insignificant fresh water sources can easily "infiltrate" the system. In aggregate these sources can account for very significant levels of fresh water within the recycle system. However, continued studies developments, and system improvements will be made, which are aimed at better control of fresh water intrusion and overall system hardware development to reduce system discharge; since the goal of zero discharge continues to be a goal of Owens-Corning Fiberglas Corporation.

CHAPTER II

CONCLUSIONS

Analysis of data obtained from the full scale operating waste water reclaimation and reuse system at the Owens Corning Fiberglas, Anderson, S.C. Fiber Reinforcement Manufacturing Plant over a 9-month evaluation period has produced the following conclusions:

1. Total system closure has not been achieved because fresh water use has not been controlled to levels of design expectations.

   a) Excess fresh water usage of approximately 87 to 100 gpm should be controllable in the future since it is result of maintenance related items, treatment of surge inadequacies and surge control inadequacies present in the existing system.

2. Primary, secondary and advanced waste treatment (AWT) (consisting of sand filtration, activated carbon adsorption and chlorine disinfection) systems hydraulic patterns should be and are presently being modified to increase hydraulic surge (flow) capacity which should decrease excess fresh water usage by 10 to 25 percent.

3. Reuse patterns within the manufacturing facility have been modified and include:

   a) Elimination of fresh water usage and utilization of reclaimed water to clean combustion gases in the inert gas scrubbing unit.

   b) While dissolved air flotation without chemical addition is an effective pretreatment process for removal of fibrous materials from Mat Line wastewater, the utilization of reclaimed water as a pressure feed stream, rather than localized loop effluent feed stream, has been a requirement dictated by fiber fouling of pressure stream valving.

   The net effects of these changes has been to (1) lower the design level of fresh water usage by the system and allow a design closure of the system even during winter months (i.e. better system design), but (2) increase the design recycle flow rates which in turn reduces the hydraulic surge capacity within the primary, secondary and AWT systems.

4. Coagulation of equalized raw waste water with only organic polyelectrolytes in full scale trial tests has produced TSS

removal efficiences equal to or better than the originally designed ferric chloride, clay, and cationic polymer system, while significantly lowering the TDS level within all recycle streams (a design consideration which is highly favorable with respect to achieving greater reuse within all manufacturing systems and ultimate reuse success).

5. Chlorination has effectively controlled microbes and viruses within the partially closed system that has been fully segregated from domestic waste waters.

6. Reuse of treated industrial wastewaters in process areas and cooling systems at the Anderson Plant is technologically feasible with partial discharge.

7. Reclamation of the effluent from the primary and secondary waste treatment facilities by sand filtration, carbon adsorption, and disinfection will result in a product water suitable for reuse in a partially discharging system.

8. Based upon current drift loss measurement and original drift loss estimates; equilibrium concentrations of total hardness, calcium hardness, silica, sulfate, zinc and organic materials in the cooling systems may exceed the water quality criteria for these uses; if drift loss, is the sole mechanism by which inorganic and residual organic dissolved solids are removed from the reclaimed wastewater in a totally closed system.

9. If removal of inorganic dissolved solids is required, it could be accomplished through treatment by reverse osmosis or lime-soda softening/anion exchange.

10. Residual or refractory dissolved organic materials not removed through chemical, biological, and carbon adsorption treatments could be of such a nature and could accumulate to such levels within the totally closed system to reduce biological treatability which might prove to be significant upon the ultimate zero discharge system design.

11. Maintenance of high performance efficiencies with the secondary systems has been much more difficult following sanitary waste segregation and requires much closer attention of nutrient supplementation. Secondary system performance has faltered due to:

    (a) nutrient difficiencies, (b) hydraulic overloading produced by excess fresh water intrusion and treatment system hydraulic pattern design as described in conclusions 1, 2, and 3 above and (c) possibly refractory dissolved organic materials resulting in higher than expected organic concentrations in reclaim water. Even

with partial discharge cooling systems have not failed to date. The only major total system purge to date has been due to residual sulfide odors within the entire manufacturing plant water system produced by anaerobic biological activity within the carbon adsorber due to high biological suspended solid loadings upon the adsorber.

12. Dynamic manufacturing operations resulting in numerous product changes present a 'moving target' for the design and operation of reclaim water treatment processes.

13. Total system success related to inorganic & organic quality can only be assessed after complete hydraulic closure for an extended time period.

CHAPTER III

RECOMMENDATIONS

Upon evaluation of the proposed closed loop system over six months of preliminary operation, plus additional operation over a nine month extensive testing program documented within this report, the following recommendations regarding the closed loop system development are made:

1. Continue system upgrade and development to reduce uncontrolled fresh water addition such that zero discharge might be achieved on a hydraulic basis.

2. Modify recycle and reuse patterns to optimize reuse potentials through utilization of more reclaimed water and the decrease of designed fresh water usage as presented in Chapter VI.

3. Modify the original design of the advanced waste treatment system (AWT) hydraulic flow pattern for backwash wastes as presented in Chapter VII, to increase surge capacity of the AWT system and lower the hydraulic loads upon primary and secondary treatment systems.

4. In the future, when preliminary design analyses of recycle system concentration projections are made, include an impact study of organic residuals escaping biological and physiochemical treatment similar to that made for inorganic parameters.

5. During preliminary design of similar systems, evaluate the seasonal impact of precipitation upon volumetric increase of uncovered storage basins. The annual effect may be negligible with evaporation exceeding precipitation, however short term seasonal variations may be critical to hydraulic balance.

6. After hydraulic closure is achieved, re-evaluate system operation with respect to inorganic and residual organic build up. These impacts should be studied as they affect cooling system operation and treatment system performance. Furthermore, high and low quality treatment schemes, tailored to meet demand quality might evolve which could make overall recycle economics more favorable.

7. The following recommendations are made either as (1) a contingency if overall hydraulic closure is never achieved or (2) for future systems which might be designed on the basis of partial system closure:

    a) Investigate the impacts of polutant concentration and pollutant mass rate discharges upon receiving enviorn-

ments; a partially closed system, with internal advanced waste treatment, should most certainly reduce the rate of mass discharged with respect to a corresponding once through system, however, concentrations of most pollutants may be significantly larger (due to partial closure) than the corresponding once through system. Thus, discharge standards with respect to concentration limits must not only be consistant with receiving environment needs, but also be consistant with treatment system concepts relating to partial reuse.

CHAPTER IV

PLANT WATER & WASTE WATER CHARACTERISTICS

IV.1. OVERALL RECIRCULATION SYSTEM PLAN

Based upon numerous hydraulic flow studies made in 19[illegible], 1973 through 1974 and in 1976, it was estimated that flow closure would be quite reasonable. These data were presented in detail in the Preliminary Engineering Report (1). Detailed analysis of these data indicated the following reuse scheme:

1. Upgrade existing wastewater treatment facilities to enable production of an effluent of such quality as may be used in the plant cooling systems.

2. Utilize this reclaimed water as makeup to the cooling systems.

3. Cascade blowdowns from one cooling system to another; thus, in effect, the blowdowns will be part of the makeup to the systems receiving them.

4. Final blowdowns from the cooling systems are to be routed to the "D" and "E" factory air scrubbers.

IV.2. COOLING SYSTEMS

There are nine major cooling systems in the Anderson plant which use water; these are described in Table 4.1. The process cooling systems require the highest degree of water quality due to extreme heat loads and small diameter heat exchanger piping. The chillers possess somewhat liberal physical and chemical water quality requirements, but the water used must be free of pathogenic bacteria and viruses, because the chill water is used to cool the atmosphere inside each factory. Thus, the sanitary wastes generated within the plant were completely segregated from industrial discharges to assure that this requirement would be continuously met.

IV.2.1 COOLING SYSTEM HYDRAULIC OPERATION

Cooling of heated circulating water in evaporative cooling systems employed at the Anderson plant is accomplished primarily through evaporation in spray ponds and cooling towers. Additional water is also lost whrough entrainment of water droplets in the air draft; this loss is know as "drift". While both evaporation and drift constitute vapor losses, of the two mechanisms only the drift process is responsible for dissolved solids removal. The overall effect is that the dissolved solids concentrate in the remaining liquid. To prevent a buildup of dissolved solids in the cooling systems (and associated scaling produced heat transfer problems) a small portion of

TABLE 4.1

MAJOR COOLING SYSTEMS

SYSTEM	PURPOSE	VOLUME (gal)
"A" Chillers	Cools water for "A" Factory and Beta Factory air washers	20,000
"E" Chillers	Cools water for "E" Factory air washers	38,000 *
"D" Chillers	Cools water for "D" Factory air washers	38,000
#1 Pond (A" & "E" Condenser Cooling)	Cools refrigeration units in "A" Factory, Beta Factory, and "E" Factory	755,000
#2 Pond ("A" & "E" Process Cooling)	Cools bushings, fin shields, and furnace coils in "A" Factory, Beta Factory and "E" Factory	505,000
"D" Condenser Cooling	Cools refrigeration units in "D" Factory	38,000
"D" Process Cooling	Cools bushings, fin shields, and furnace coils in "D" Factory	135,000
Chemical Cooling Tower No. 2	Cools Chemical Factory process units: #2 Thinning Tank, #2, #3, and #4 Reactors, and Carrier chill water condensers	6,000
Chemical Cooling Tower No. 1	Cools burner in the Chemical Factory Inert Gas manufacturing operation, #1 Reactor, and Trane chill water condensers	2,000
		1,537,500

* Estimated volume

the circulating water is continuously discharged from the cooling water system; this loss is termed "blowdown". The end result is that water is continuously added to each system (makeup) in amounts equal to the total water lost (blowdown + evaporation + drift - chiller condensation during summer months).

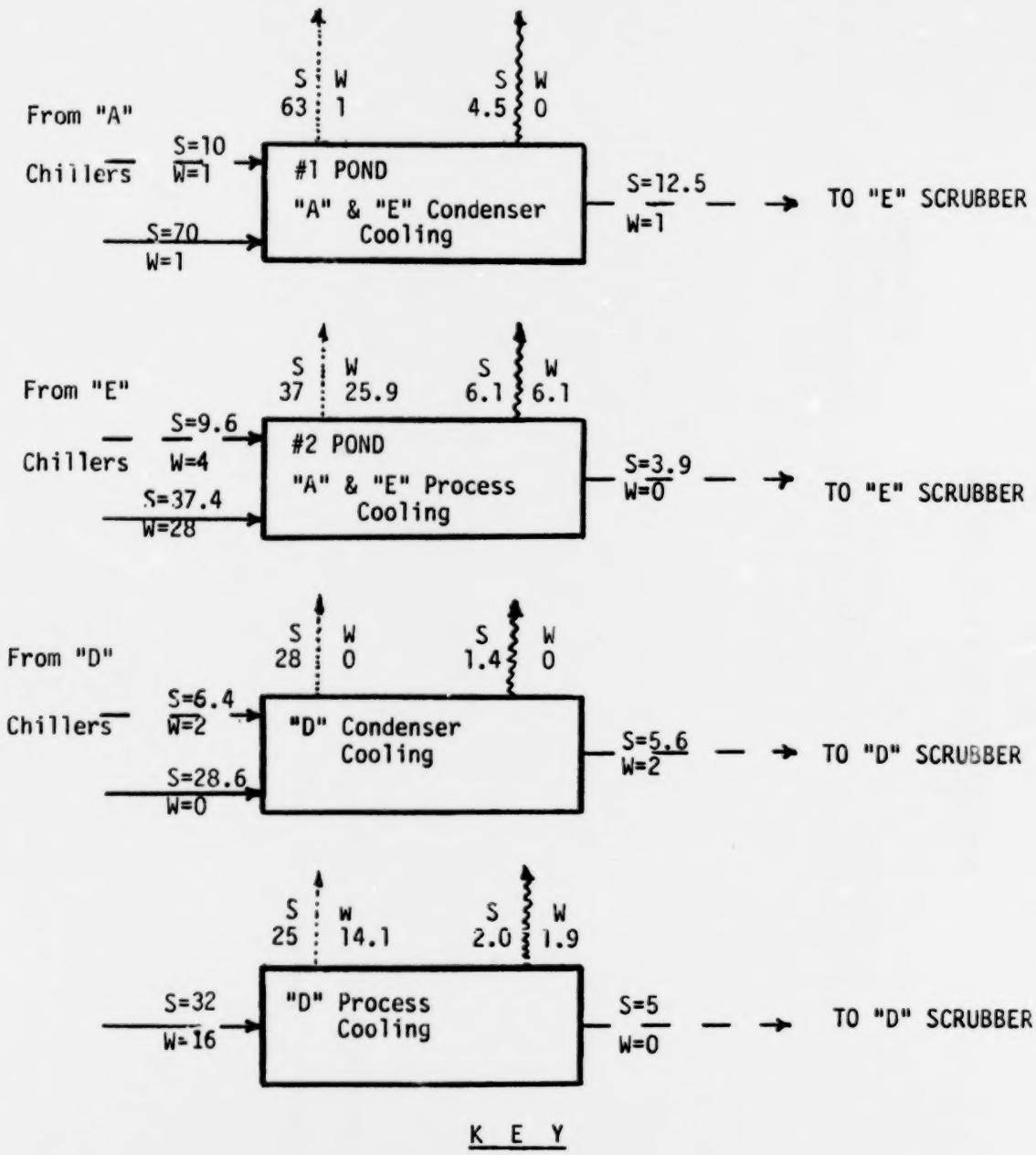
Makeup, blowdown, evaporation, and drift flows for both summer and winter operating conditions for all nine major cooling systems were calculated and presented in the preliminary report (1). Four of these systems are presented in Figure 4.1 these projections for #1 and #2 Spray Ponds and "D" Process and "D" Condenser cooling towers are contrasted to those measured during a recent two (2) week winter period with attempted system closure. The operational data appear in Table 4.2. These data indicate that all systems were being turned over through system blowdown to scrubbers at higher rates than in the original design. Larger blowdown rates were necessary to purge scrubber systems since scrubbers were accumulating suspended and dissolved solids. In the future, various chemical dispersants will be tested to achieve higher levels of suspended and dissolved solids build up within scrubber systems. In turn this will decrease the cascading blowdown requirements from the process and condenser cooling systems, and correspondingly slightly reduce overall wastewater discharge and reclaim supply demand flow rates.

IV.3. HYDRAULIC BALANCE BETWEEN RECYCLE DEMAND AND WASTEWATER DISCHARGE

Projected wastewater flows and reuse requirements were developed from cooling system balances, previously cited process reuse flows developed in 1974, planned manufacturing reductions in "A" Factory and Beta Factory, and future manufacturing additions ("E" Factory). Sanitary wastewaters from the entire Anderson Plant, amounting to 40-60 gpm were segregated from the process wastewater conveyance system, treated separately in a "package" plant, and discharged to Betsy Creek. The sanitary waste originates from potable city water uses in the plant lavatories and cafeterias. Usages requiring high quality water, such as boiler makeup, binder makeup, and deionized water sprays do not utilize reclaimed wastewater. Finally, reclaimed wastewater is used in the process cooling systems, the air scrubbers, Mat Line, Alloy, and floor washdown in "A", "D", and "E" Factories. Currently reclaimed water is also used as input to the IG Scrubber.

Both projected cooling and process reuse flows, together with projected wastewater discharges, are listed in Table 4.3. Since cooling system evaporative losses are much greater during the summer than during the winter, summer reuse requirements were planned to exceed the amount of reclaimed wastewater available; conversely, during the winter reclaimed wastewater flows were planned to exceed reuse requirements. The obvious conservation solution was to store the excess reclaimed water during the winter for later use in the

FIGURE 4.1 SELECTED COOLING SYSTEM WATER BALANCE



K E Y

Reclaimed Water Makeup

Evaporation

Blowdown

Drift

S = Summer Conditions, Flow, GPM

W = Winter Conditions, Flow, GPM

TABLE 4.2

SELECTED COOLING SYSTEM SUMMARY

TYPE OF FLOW	#1 SPRAY POND		#2 SPRAY POND		"D"-PROCESS COOLING		"D"-CONDENSER COOLING	
	Projected	Measured	Projected	Measured	Projected	Measured	Projected	Measured
Total Makeup (gpm)	41	40	39	48	24	24	18	16
Blowdown to Scrubbers (gpm)	7	8	2	6	2	4	3	4
Drift (gpm)	2	6 *	6	8 *	2	3 *	1	2 *
Evaporation (gpm)	32	26 **	31	34 **	20	17 **	14	10 **

* Through Differential Calculation

** Through Data Measurement and Computation

TABLE 4.3

COMPARISON OF PROJECTED WASTEWATER AND RECIRCULATION FLOWS WITH 1979 DATA DURING RECYCLE

SOURCE	PROJECTED REUSE DEMAND SUMMER	PROJECTED REUSE DEMAND WINTER	AVG. DESIGN DISCHARGE	MEASURED DISCHARGE FEB. 1979	% INCREASE OR DECREASE
	gpm	gpm	gpm	gpm	
"A" Factory Process	10	10	15	--	--
Marble Fact./Binder Room	0	0	2	--	--
Boiler House	0	0	5	--	--
Cooling System Filter Backwash (1)	1	1	1	--	--
All Plant Cooling Systems	174.3	89.6	1	--	--
Miscellaneous	10	10	19	--	--
SUB-TOTAL	195.3	110.6	43	147	+ 242
"D" Factory Process	20	20	25	--	--
"D" Scrubbers (2)	.4	9	11	--	--
SUB-TOTAL	20.4	29	36	76	+ 111
"E" Factory Process	20	20	25	--	--
"E" Scrubbers (2)	3.6	19	20	--	--
SUB-TOTAL	23.6	39	45	47	+ 4.4
IG Scrubber (3)	0	0	--	37	--
Mat Line (4)	0	0	--	19	--
SUB-TOTAL	0	0	26	56	+ 115
Chemical Factory Process	0	0	35	25	- 28.6
Alloy	20	20	20	10	- 50
TOTALS	(259.3)1.1 (5) =285	(198.6)1.1 (5) =219	(205)1.1 (5) =226	(361) 1.1 =397	59.7

(1) Wastewater flow is Chemical Cooling Tower No. 1 System Blowdown; reuse flows are totals for all cooling systems.

(2) Both scrubbers receive cooling systems blowdown in addition to flows listed in reuse columns.

(3) Originally conceived to be supplied with fresh water and supplied with fresh water during February, 1979; currently supplied with reclaim water.

(4) Originally conceived to be supplied by IG scrubber discharge (i.e. "piggyback System"): but supplied by 9 gpm fresh and 10 gpm reclaim water during February, 1979, currently operated the same as February, 1979.

(5) 110% for flow measurement accuracy limitations.

summer. However, at the time of design it was not possible to determine the balance between those days with excess wastewater and those with a deficit. The "safest" path was to: (1) make provisions for controlled addition of city water makeup to the reclaimed wastewater distribution tank and (2) ensure that the reclaimed water storage basin was of sufficient volume to hold excess flows for at least 100 days (the entire winter season).

It is important to note that system modification during system startup, involving IG Scrubber conversion from fresh water with piggyback discharge to matline processes to reclaim supply without piggyback discharge (see section VI 3.4 and VII 3.5 for details) does increase both the recycle demand and wastewater discharge flows. However, this conversion does balance the projected flows during the winter months (see Table 4.4) and theoretically eliminates the need for winter holding. Thus, it appears that this system modification, as compared to that presented in the Preliminary Engineering Report (1) is much better. Additional data obtained from hydraulic audits in February, 1979 during partial loop closure are also presented in Table 4.3. A daily average discharge on 112 gpm was measured during this period.

The overall recirculation water balance for the Anderson Plant, projected and measured, during attempted system closure is given in Figures 4.2a and b and Table 4.4. Date appearing in parentheses in Figure 4.2b are 110% average of data during the February hydraulic audit. It is important to note that the total excess flow, obtained with 110% correction for flow estimates, indicates a surplus raw wastewater flow of 397-259 = 138 gpm. Measured data at the system overflow indicates a 112 gpm x 1.1 = 123 gpm surplus flow. Recycle demand flow data also appearing in Figure 6.2b additionally indicates that the average recycle flow was measured at 245 gpm, corrected by 110%, yields 270 gpm. For complete system balance, 397-123 = 274 gpm of water should have been recycled rather than that measured, 270 gpm. Thus, a small system closure error of 4 gpm existed at the time of the audit.

IV.4. COOLING SYSTEM AND RECLAIMED WASTEWATER QUALITY

As originally conceived, the hydraulic operation (i.e., makeup and blowdown requirements including fresh water addition to the overall system) would be governed by dissolved and/or suspended solids accumulation within each recycle loop. As such, solids levels were to be monitored on a daily basis and all flows, including recycle makeup, blowdown and any fresh water addition, manually adjusted to maintain the cooling systems solids at the expected levels presented in Table 4.5. It is important to note that in the Preliminary Engineering Report (1) no projections were made regarding organic solids buildup within the system. This can be seen by inspecting the projected design equilibrium reclaimed wastewater parameters for the tertiary system illustrated in Table 4.6. It was anticipated that most biological

TABLE 4.4

COMPARISON OF MODIFIED DESIGN PROJECTIONS

WITH 1979 DATA

COMMENT OR CORRECTION	PROJECTED REUSE DEMAND SUMMER gpm	PROJECTED REUSE DEMAND WINTER gpm	AVERAGE DESIGN DISCHARGE gpm	MEASURED DISCHARGE FEB. 1979 gpm	% INCREASE
Totals from Table 4.3	259	198	205	361	----
IG Scrubber on Reclaim	37	37	(37-26)	----	----
Matline on Reclaim	20	20	20	----	----
TOTAL	1.1(316) =348	1.1(255) =281	1.1(236) =259	1.1(361) * =397	40

* Includes 37 gpm of fresh water for IG Scrubber

FIGURE 4.2a OVERALL SYSTEM MODIFIED DESIGN (1) WATER BALANCE FOR RECIRCULATION (ALL FLOWS CORRECTED BY 110%)

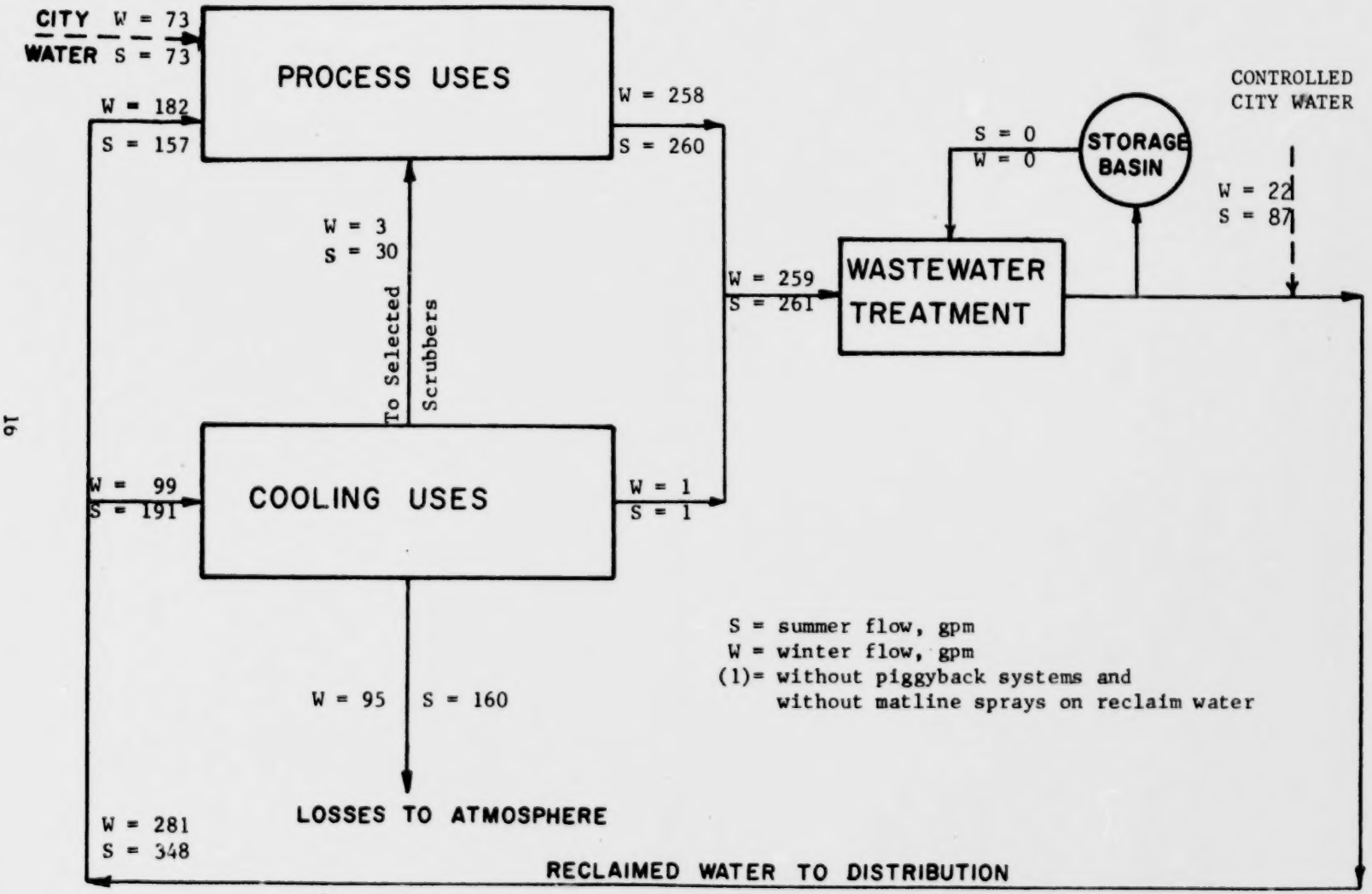


FIGURE 4.2b OVERALL SYSTEM OPERATIONAL(1) WATER BALANCE DURING PARTIAL RECIRCULATION (ALL FLOWS CORRECTED BY 110%)

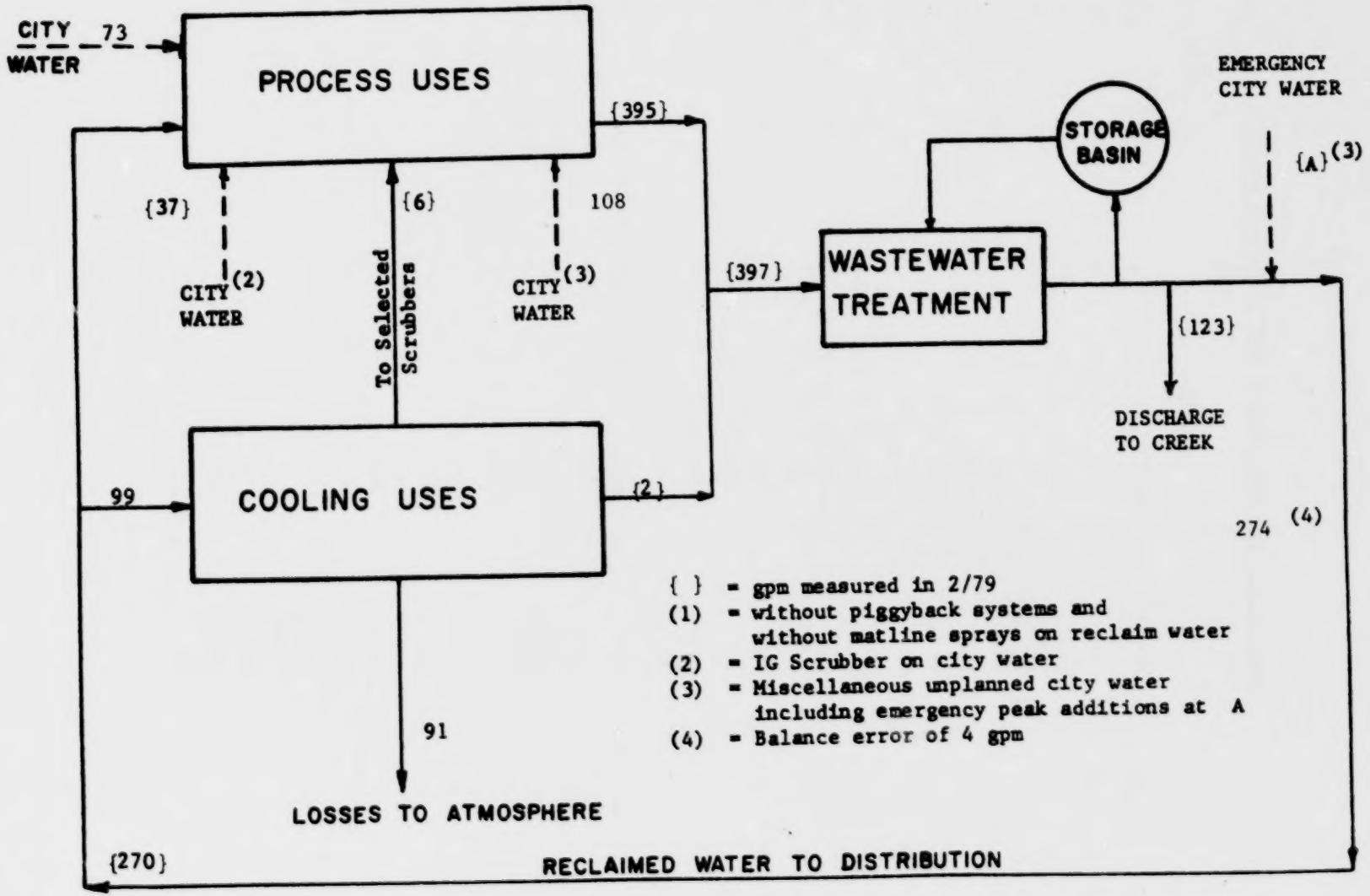


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TABLE 4.5 COOLING SYSTEM WATER QUALITY SUMMARY

		SUMMER			WINTER		
COOLING SYSTEM	PARAMETER	EXPECTED AVG.	MEASURED AVG.	MEASURED MAX.	EXPECTED AVG.	MEASURED AVG.	MEASURED MAX.
#1 Spray Pond	TDS	3470	2725	3200	1490	920	2000
	Total Hardness	443	130	160	190	85	160
	Calcium Hardness	410	-	-	176	55	60
	Silica	198	-	-	84	32.4	40.0
	Zinc	28	-	-	12	-	-
	Sulfate	876	-	-	376	174	300
	TOC	-	-	-	-	104	176
#2 Spray Pond	TDS	3460	950	2000	3910	885	2000
	Total Hardness	442	59	100	499	56	120
	Calcium Hardness	409	-	-	462	34	50
	Silica	197	-	-	220	17.6	34.4
	Zinc	28	-	-	31	-	-
	Sulfate	874	-	-	987	67	208
	TOC	-	-	-	-	72	127
"D" Process	TDS	3360	1730	2500	6260	1270	1700
	Total Hardness	429	82	160	800	64	120
	Calcium Hardness	397	-	-	741	31	50
	Silica	192	-	-	354	13.4	25.0
	Zinc	27	-	-	50	-	-
	Sulfate	850	-	-	1580	59	97
	TOC	-	-	-	-	74	128
"D" Condenser	TDS	3680	2760	3950	744	1750	4375
	Total Hardness	470	98	180	95	79	151
	Calcium Hardness	435	-	-	88	54	70
	Silica	21	-	-	42	30.9	55.3
	Zinc	30	-	-	6	-	-
	Sulfate	930	-	-	188	172	290
	TOC	-	-	-		192	400

TABLE 4.6

EQUILIBRIUM CONCENTRATIONS IN RECLAIMED WASTEWATER

	SUMMER				WINTER			
	Projected Equilibrium mg/l	Limits mg/l	Measured May - Sept 1979 mg/l		Projected Equilibrium mg/l	Limits mg/l	Measured Jan - April 1979 mg/l	
			Avg	Max			Avg	Max
Total Dissolved Solids (TDS)	736	422	512	1300	744	190	508	1150
Total Hardness	94	84	--	--	95	62	--	--
Calcium Hardness	87	76	--	--	88	55	--	--
Silica	42	42	--	--	42	30	--	--
Sulfate	186	115	--	--	188	85	--	--
Zinc	6	5	--	--	6	5	--	--
Chloride	--	--	320	570	--	--	285	500

refractory organic material would be removed by activated carbon absorbers within the tertiary system and/or subsequent treatment through the activated sludge secondary system with wastewater recycle. It has been found through system operation that this is not the case. Subsequently, the accumulation of dissolved organic solids may be a key operational limit to the system which might prevent ultimate total recycle with zero discharge on a continual basis. This specific problem is examined in greater detail in Chapter VI of this report.

The anticipated inorganic solids levels originally thought critical to the recycle system are also compared to the actual values measured during system operation between January and September 1979 and are presented in Tables 4.5 and 4.6. These data indicate that all parameters measured within cooling systems and reclaim wastewater were far below the expected levels. This finding is in agreement with the hydraulic operational findings presented in Section IV.2.1. The cooling systems were being turned over far too much and as a result, were not developing high enough concentrations of various parameters within the cooling systems. Thus, the net effect of increased drift, decreased evaporation and increased systems blowdown (Table 4.2) was to establish lower equilibrium concentrations within the cooling loops. Furthermore, large masses of residual inorganic and organic dissolved solids have been continuously removed from the overall system through the continual average partial discharge of approximately 86 gpm* of reclaimed waste water.

For example, the estimated rate of total dissolved solids input through fresh water and manufacturing losses (after treatment) was estimated in Appendix A to be 728 lbs/day while the estimated TDS loss rate through partial discharge alone was 527 lbs/day. Assuming that the TDS levels were pseudo steady, this would indicate a need of 201 lbs/day less through cooling system drift. However, an estimate of the total system drift loss, if all cooling systems were drifting as estimated in the preliminary report (1) would be 425 lbs/day.

Thus, increased cooling system drift (Table 4.2) plus partial system discharge could easily produce lower than expected equilibrium concentration levels within the overall system. Nevertheless, Figures 4.3, 4.4, 4.5, and 4.6 contain graphical documentation of cooling system chemical parameter weekly variations.

In summary, no conclusion can be made regarding either system tolerances and failures related to solids build up or the need for additional solids removal treatment within recycle systems. Only after operation of a completely closed system over an extended time period can such information be obtained.

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*123 gpm discharge includes 37 gpm freshwater on IG Scrubber during 2 week audit. Therefore, over 9 month period average discharge estimated at 123-37 - 86 gpm.

FIGURE 4.3 WEEKLY AVERAGE HISTORY OF #1 SPRAY POND COOLING SYSTEM AND RECLAIM SUPPLY WATER

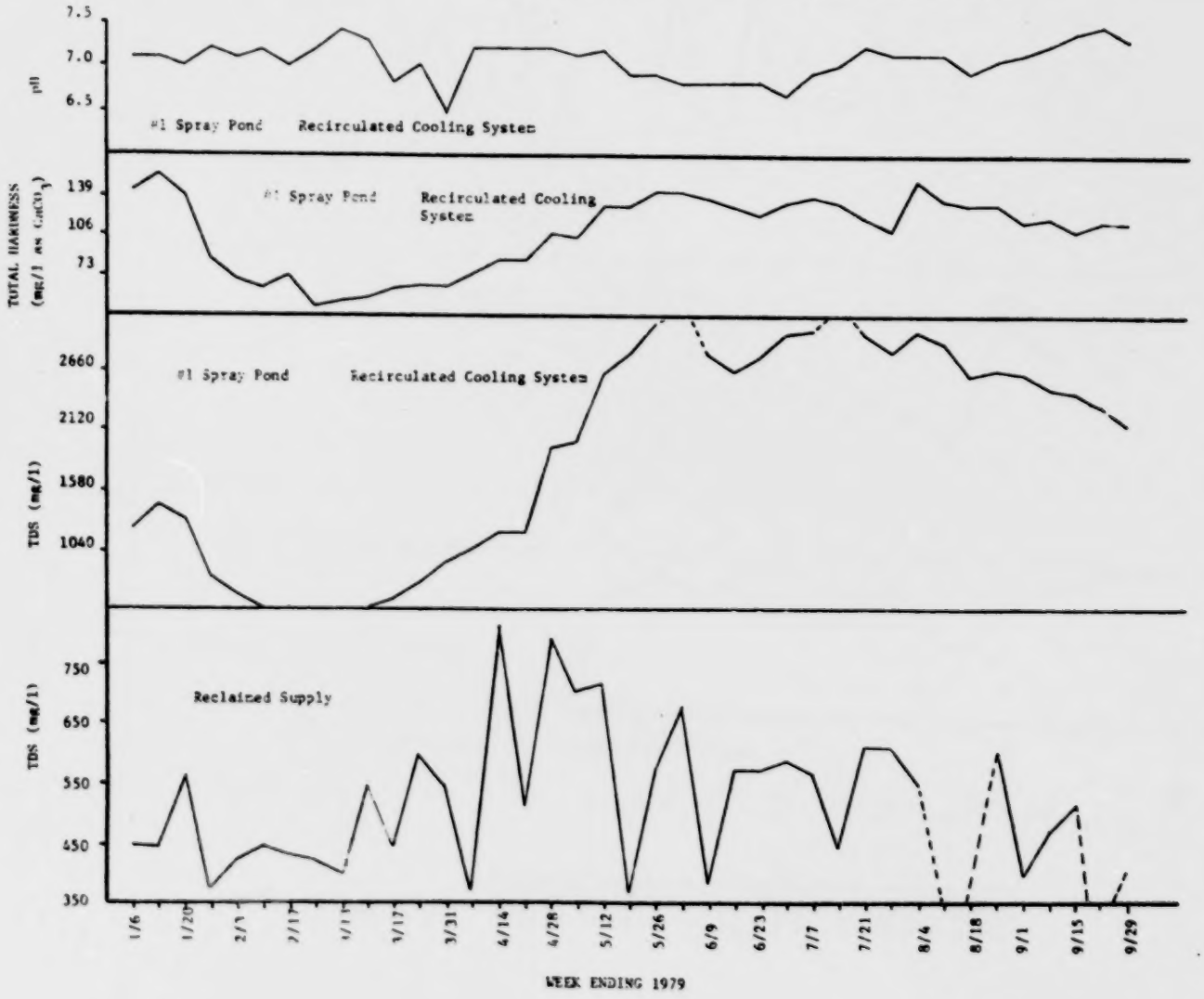


FIGURE 4.4 WEEKLY AVERAGE HISTORY OF #2 SPRAY POND COOLING SYSTEM AND RECLAIM SUPPLY WATER

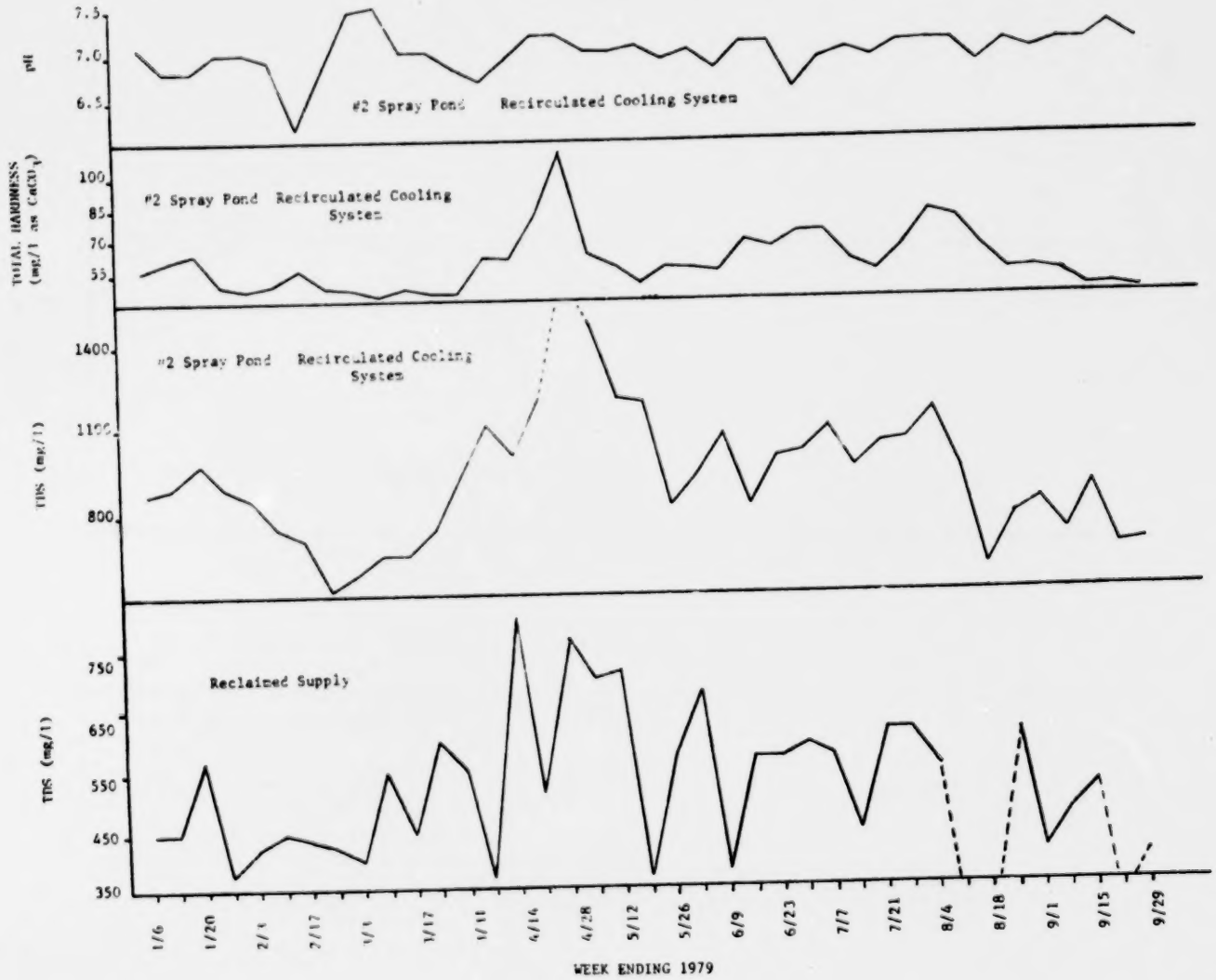


FIGURE 4.5 WEEKLY AVERAGE HISTORY OF "D" PROCESS COOLING SYSTEM AND RECLAIM SUPPLY WATER

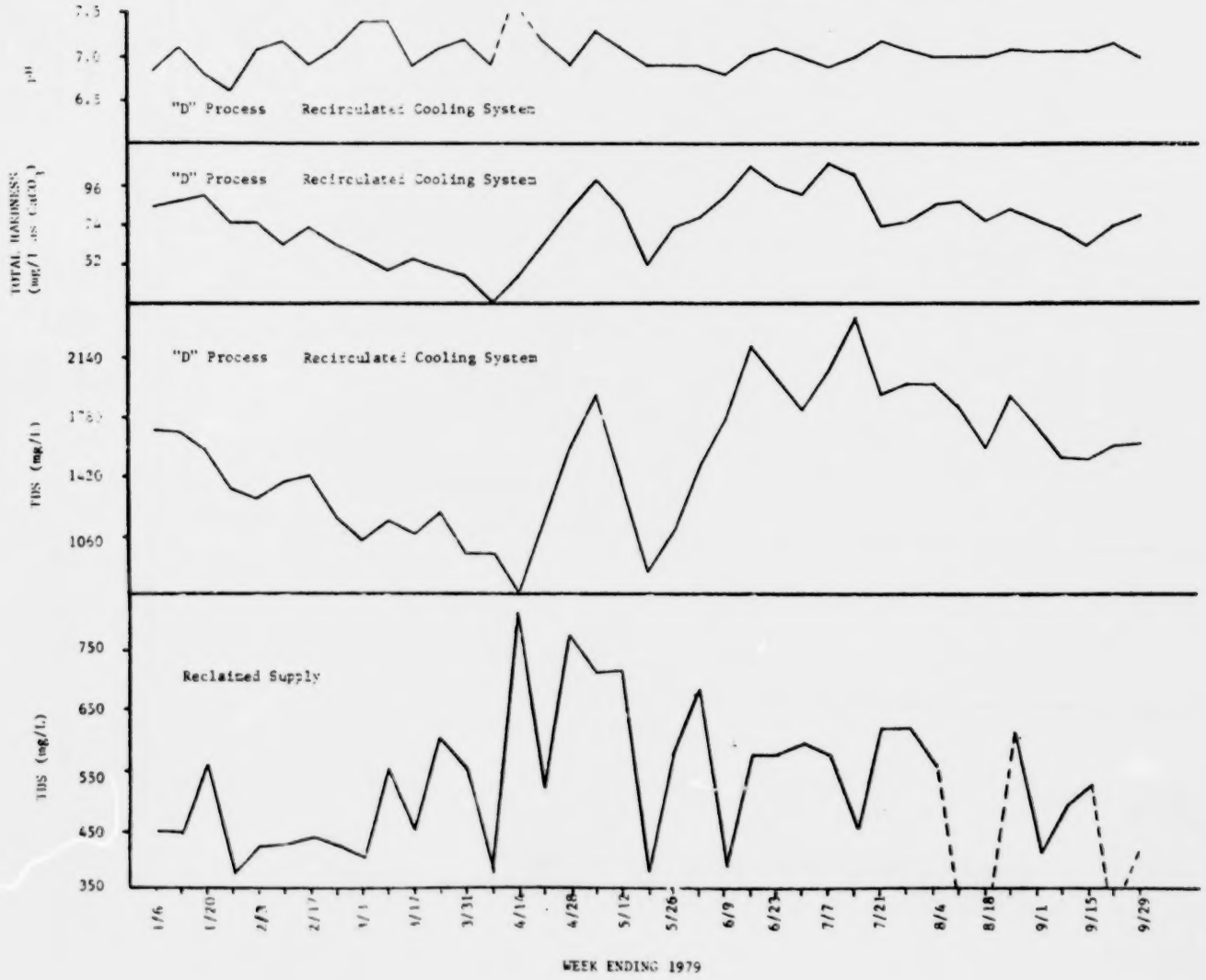
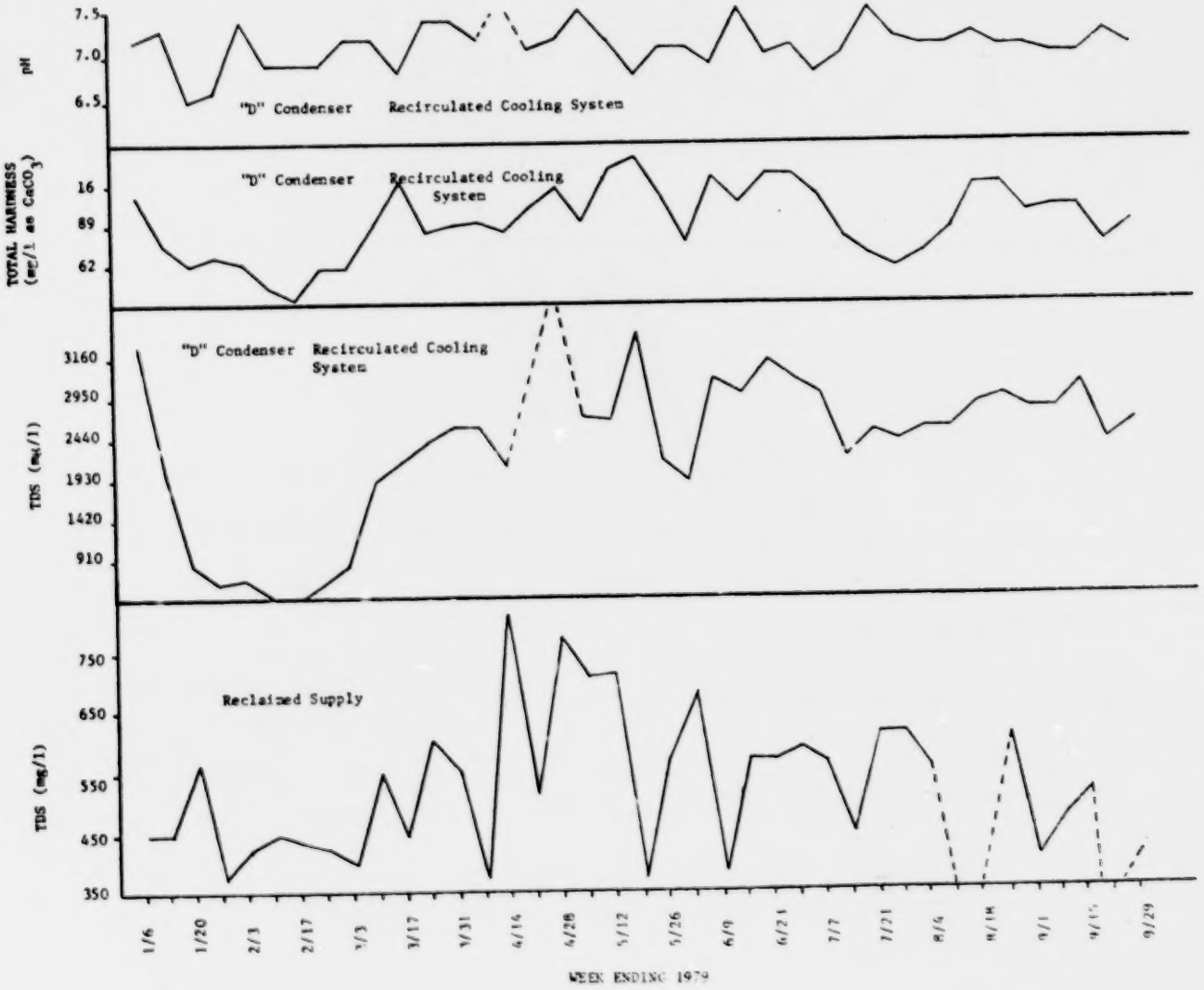


FIGURE 4.6 WEEKLY AVERAGE HISTORY OF "D" CONDENSER COOLING SYSTEM AND RECLAIM SUPPLY WATER



CHAPTER V

OPTIMIZATION AND OPERATIONAL IMPROVEMENTS TO EXISTING PRIMARY AND SECONDARY TREATMENT SYSTEMS

V.1 SYSTEM DESCRIPTION

An extensive backlog of historical development and data has been published regarding the waste treatment systems at the Owens Corning Fiberglas, Anderson Plant, including:

1. Thomas, S.H., and Walch, D.R., "An Industrial Wastewater Recirculation System for the Fibrous Glass Textile Industry", Textile Industry Technology Conference, 1978, (3).

2. "Industrial Wastewater Recirculation: Preliminary Engineering": EPA-600/2-77-043. February 1977, (1).

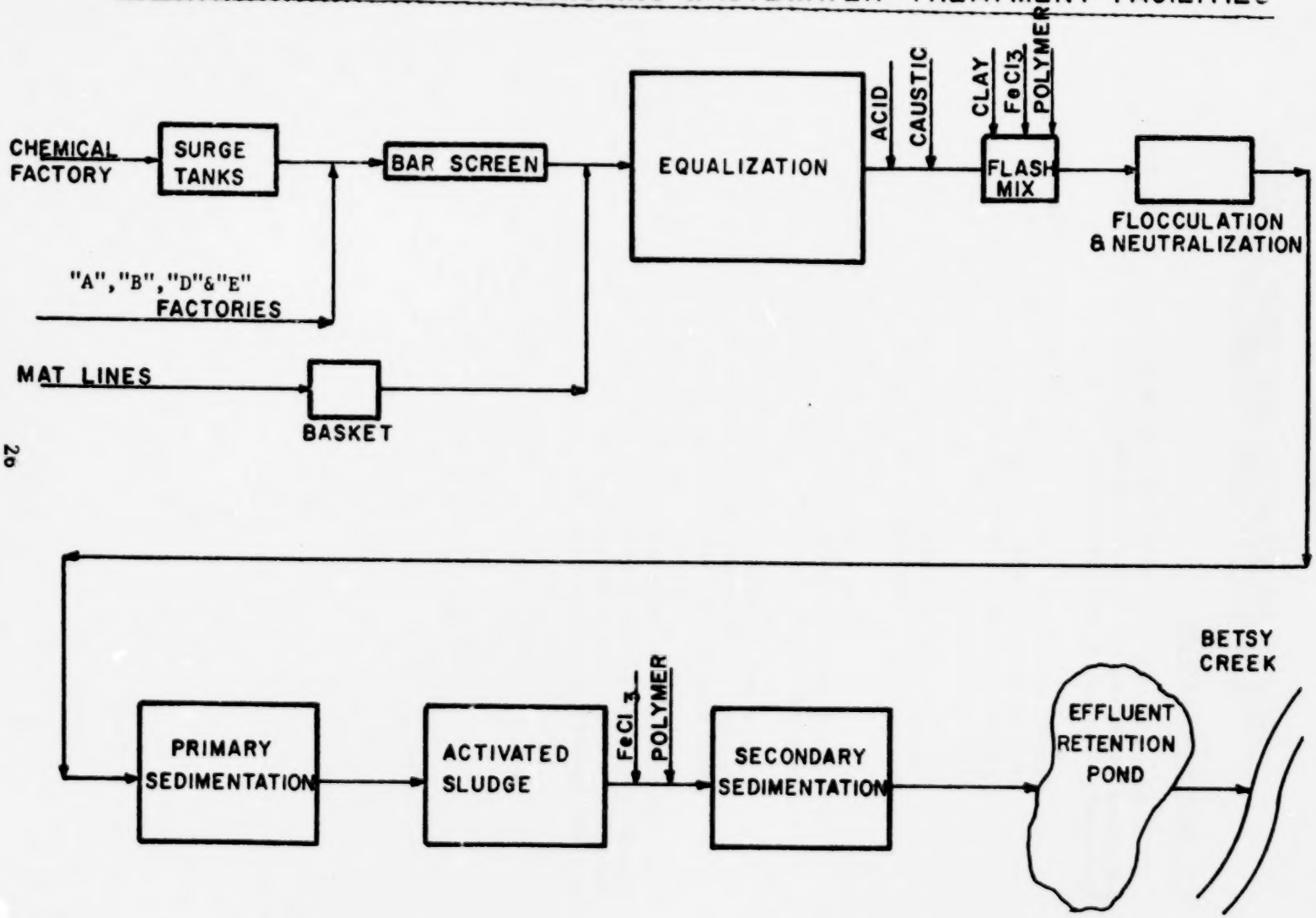
3. West, A.W., "Plant Performance at the Owens-Corning Fiberglas Corporation Wastewater Treatment Facility, Anderson, South Carolina", EPA, December 1973, (4).

4. Pharis and Monaghan, "Biological Treatment of Textile and Sanitary Wastes from a Fiberglas Plant" WPCF Conference, 1965, (5).

The Preliminary Engineering Report (1) described waste treatment operational activity in detail up to 1977. The existing waste treatment facility process flow diagram prior to the wastewater recirculation project appears in Figure 5.1.

FIGURE 5.1

PROCESS FLOW DIAGRAM - EXISTING WASTEWATER TREATMENT FACILITIES



V.2 SYSTEM PERSORMANCE

A performance summary of the existing treatment facilities from 1972 up until mid-1976 is presented in Table 5.1. However, during the winter of 1976-1977, plant treatment efficiency began to decrease. Review of the operational data at that time indicated that loss of performance could be associated with an abnormally cold winter season. Thus, a preliminary investigation involving temperature control through the use of heaters and/or an air supported dome covering the biological waste process of the existing facility was undertaken. This investigation was found to be extremly cost prohibitive. Furthermore, by early spring of 1977 treatment efficiency began to dramatically recover. The treatment performance is typically illustrated in Figures 5.2, 5.3, 5.4 and 5.5 in the form of historical plots of weekly average TOC & BOD data during the period of June through August 1977. The mean effluent BOD and TOC were 37 ± 15 and 56 ± 15 mg.1. The mean TOC removal within the primary system was 62.5 percent and the mean TOC removal within the secondary system was 71.2 percent.

V.3 PERFORMANCE IMPROVEMENT STUDIES

Beginning in October 1977, performance again faltered; however, these winter temperatures were not as low as the previous winter and other problems associated with poor performance were explored. This led to: evaluating waste treatment biokenetics through pilot studies by contracting external consultants, a detailed "in-house" investigation of changes in waste composition, and a detailed "in-house" appraisal of nutrient effects upon waste treatment. All three studies were undertaken simultaneously to improve system performance shortest possible time. The results of the materials inventory-waste composition study are presented in Table 5.2. A dramatic difference in waste composition between 1973, during the EPA West study (4), and September 1976, a period of equally good waste treatment plant performance, was noted. Epoxy and PVA components dramatically increased and starches and polyester components dramatically decreased, yet the bio-treatment system apparently handled these changes. Furthermore, these changes were consistent with manufacturing trends within the facility, when in early 1976 the Anderson plant changed from intergrated glass textile and reinforcements manufacture to glass reinforcement manufacture only. Comparison of September 1976 to November 1977, a time period of plant upset, revealed no significant difference in the composition of wastewater. Composition was further evaluated during the period of treatment plant recovery in three successive weeks in March 1978. Again, no significant changes in waste composition were observed.

The results of a comprehensive pilot study undertaken to determine biological kinetics on the waste indicated that Monod or modified Monod kinetics could not be obtained using either BOD or TOC as a variable of limiting carbon. During these studies nutrient limitation appeared to justify these results; however, a detailed mass balance of nitrogen and

TABLE 5.1

PAST PERFORMANCE SUMMARY OF PRIMARY AND SECONDARY SYSTEMS

MEAN VALUES

YEAR	FLOW (gpm)	BOD_5[1]			COD[1]			TOC[1]			TSS[1]		
		PI[2]	PE[3]	SE[4]	PI	PE	SE	PI	PE	SE	PI	PE	SE
1972	335	369	-	14	1352	614	141	-	-	-	440	94	23
1973	374	450	348	18	1712	847	220	-	-	-	553	143	35
1974	333	528	-	19	1975	764	226	-	-	-	617	114	18
1975	296	313	-	11	1233	477	124	376	150	32	396	56	8
1976[5]	303	255	-	10	-	-	-	452	139	36	604	59	13

1. Concentration in terms of mg/l.
2. PI = primary clarifier influent.
3. PE = primary clarifier effluent.
4. SE = secondary clarifier effluent.
5. Values are for five months operation.

FIGURE 5.2 WEEKLY AVERAGE HISTORY OF EXISTING WASTE TREATMENT OPERATION - TOC

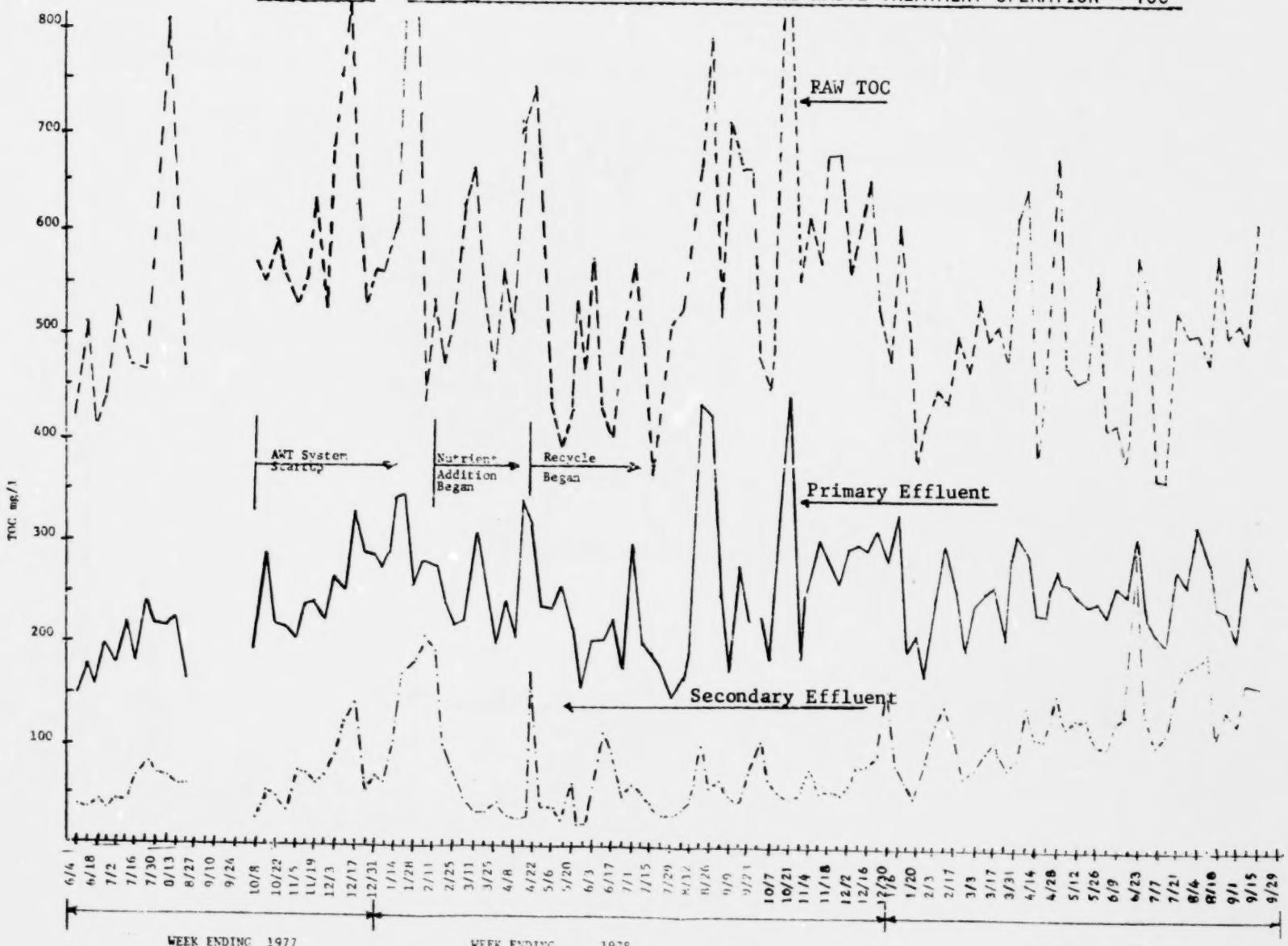


FIGURE 5.3

WEEKLY AVERAGE HISTORY OF EXISTING WASTE TREATMENT OPERATION - BOD

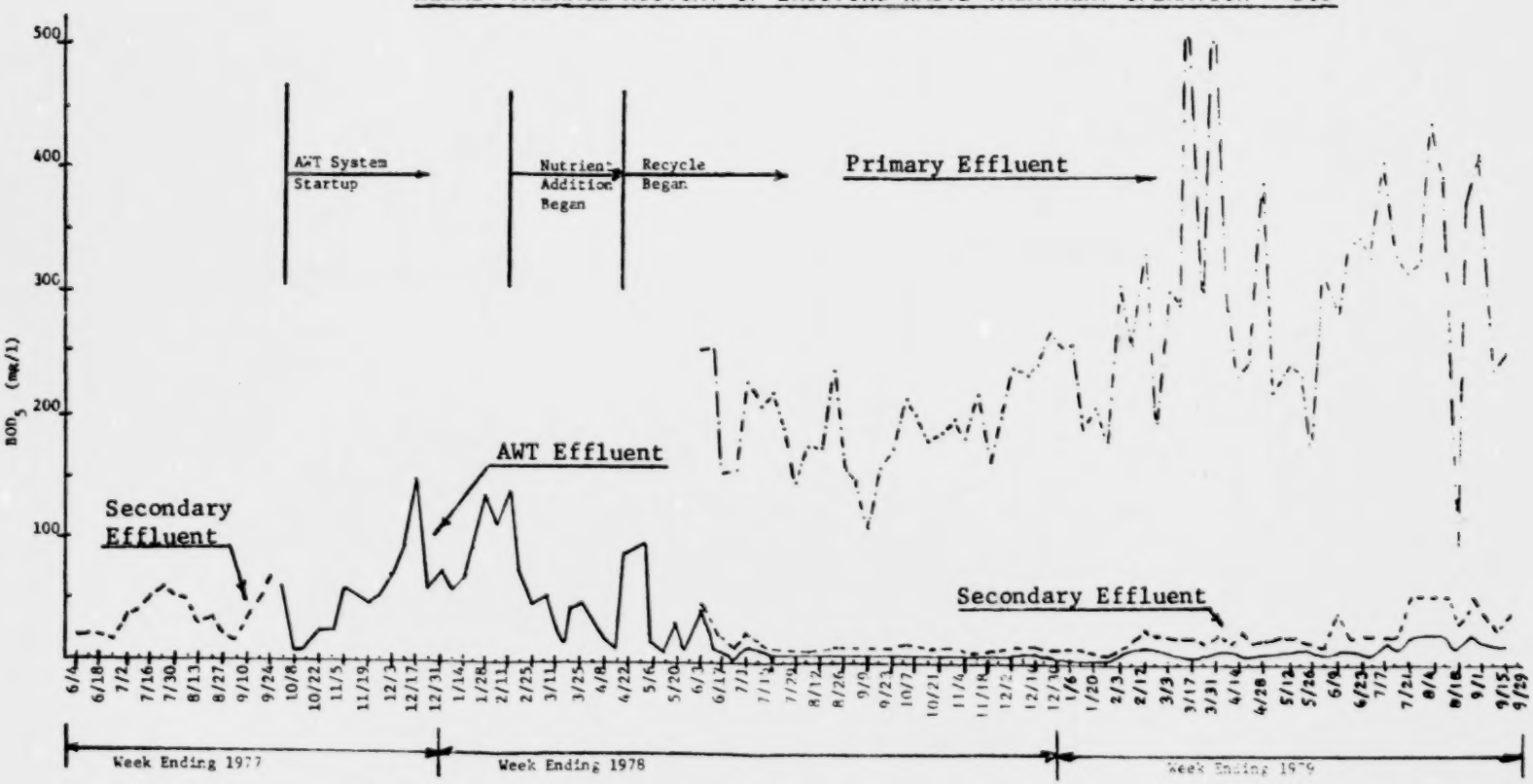


FIGURE 5.4

BOD AND TOC REMOVAL EFFICIENCY IN SECONDARY SYSTEM

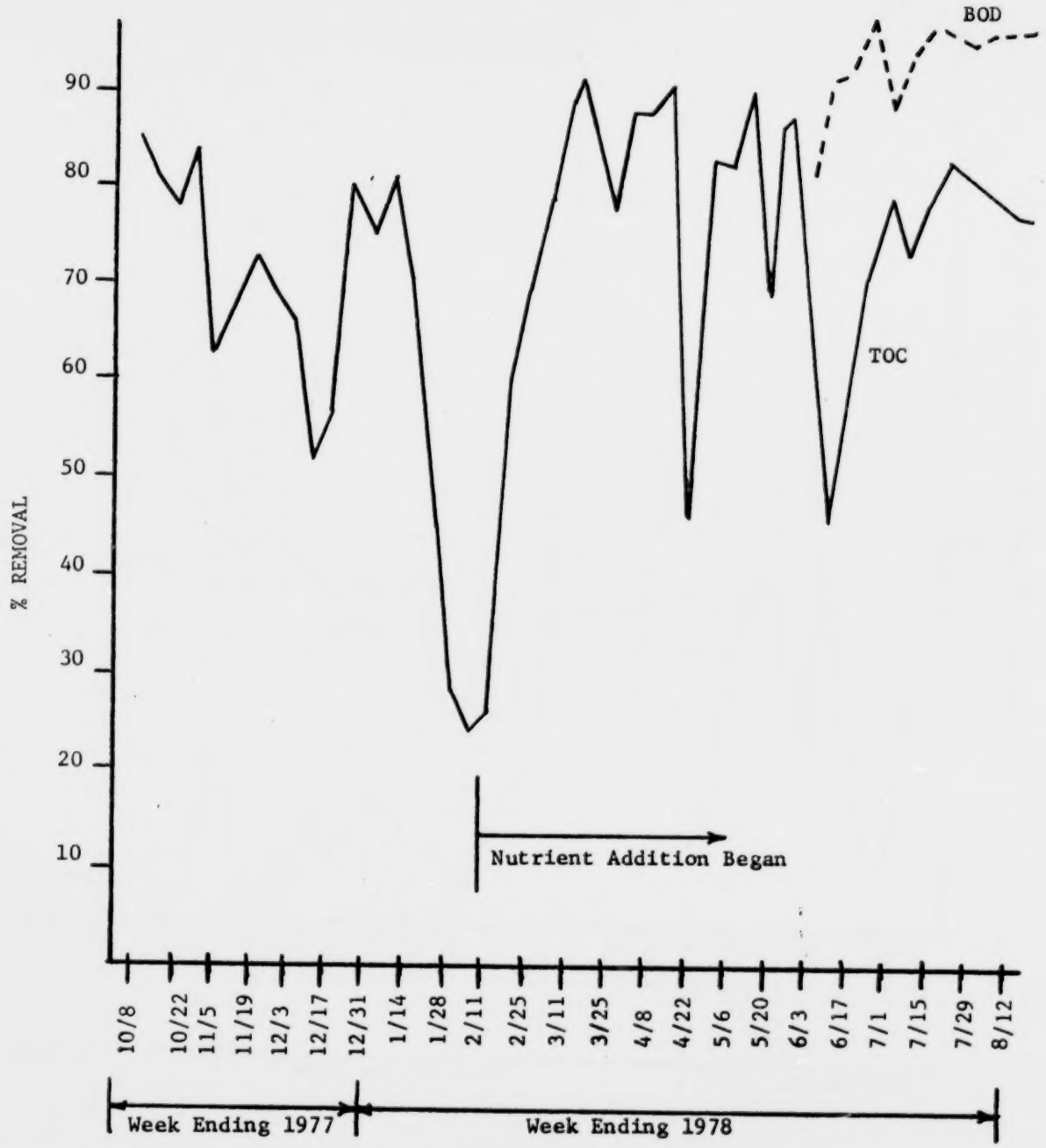


FIGURE 5.5 SECONDARY SYSTEM PERFORMANCE HISTORY
SUSPENDED SOLIDS

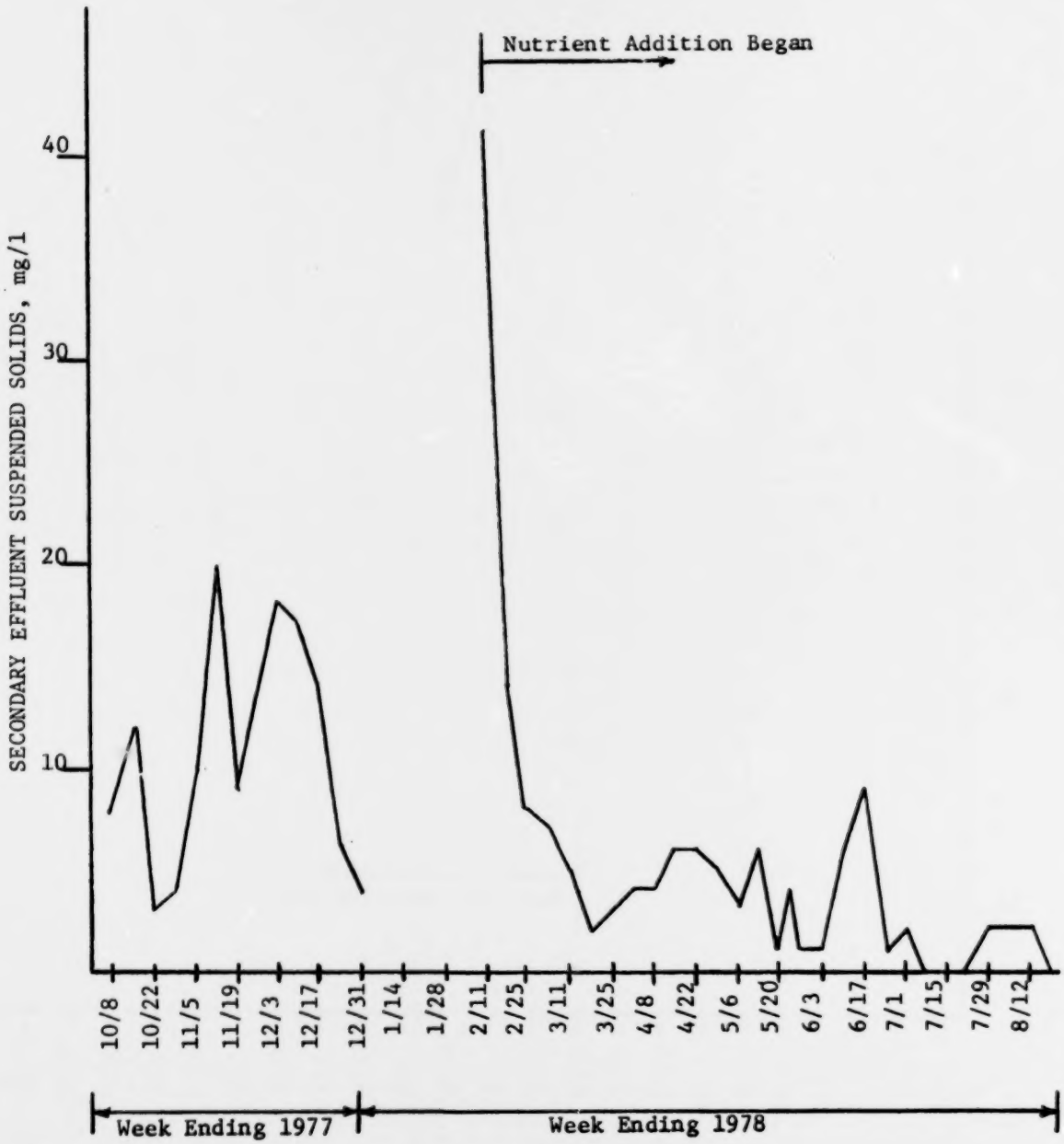


TABLE 5.2

SUMMARY ESTIMATED WASTE COMPOSITION

	A. EPA Study West Group Report 1973	Waste Treatment Plant Peformance				
		Good Sept. 1976	Poor Nov. 1977	Intermediate Bio Performance Week of 3-1-78	Week of 3-8-78	Week of 3-17-78
Polyvinyl Acetate	26%	32.2	27.7	33.6	35.8	37.1
Polyester	27%	1.0	4.2	8.6	5.4	4.1
Starch	14%	0	0	0	0	0
Epoxide	5%	41.9	42.0	36	31	31
Silicone	5%	6.9	5.9	4.9	4.7	4.2
Oil	4%	1.1	.9	1.7	1.7	2.1
Aromatic Polyether	5%	----	----	----	----	----
Polyolefin	2%	.2	.8	0	0	0
Acetic Acid	1%	1.4	1.3	1.5	1.3	1.3
Polyurethane	2%	2.1	1.3	.82	1.14	3.5
Poly(oxy)ethylene Glycol	3%	9.6	13.2	8.9	11.5	12.3
Polyvinylproyollidone	2%	.9	.6	.45	.35	.28
Dispersants		.04	.05	.11	.103	.104
Acetone		.6	--	0	0	0
Citric Acid		.0003	.03	0	.07	.07
Formic		.0004	.04	0	.1	.1
Chromic Compounds		.5	.9	2.52	3.07	3.42
Ammonium Chloride & Hydroxide		1.1	.3	.88	.77	.76
TOTAL %	96%	99.9	100.5	98.4	95.8	99

phosphorous in the full-scale system indicated that they were not limiting since total phosphorous, nitrates, and ammonia routinely appeared in the full scale plant effluent at approximately 0.5 mg/l as P, 0.02 mg/l as NO_3^-, and 0.9 mg/l as NH_3, respectively. Initially, there was reluctance to evaluate increased nutrient addition in the full-scale system since the nutrient residual values in plant effluent would most probably increase to even higher levels than those previously cited. However, during the first week of February 1978, nutrient supplementation was increased to levels outlined in Table 5.3. The treatment plant responded by a dramatic recovery as illustrated in historical plots contained in Figure 5.4. By May 24, 1978, the treatment plant appeared to be in a full state of recovery and the typical nutrient supplementation program outlined in Table 5.3 was adopted. Furthermore, a nutrient supplementation program would more likely be needed after segregation of sanitary wastes from the industrial waste treatment system.

Prior to system recovery, the advanced waste treatment system was constructed and started up. However, sanitary segregation and reclaim supply systems were not completed until March 15, 1978 and April 16, 1978, respectively. Thus, during the winter of 1977-78 the tertiary system was operated with the total plant effluent being discharged. As a matter of record, the tertiary treatment systems did help overall treatment efficiency during the winter upset; however, even with tertiary treatment, effluent discharge parameters were quite often above those specified in the discharge permit. It became apparent that if nutrient addition did not permanently solve the "winter upset condition", even with the operation of the tertiary treatment system during these winter upsets, closed loop recycle plans not only could be jeopardized, but also discharge standards would not be routinely achieved!

Presently only one winter has transpired since the nutrient system was adopted. Treatment plant performance data for the entire year of 1978 and the 9-month system evaluation period from January through September also appears in Figure 5.2, 5.3 and 5.4. As illustrated, the winter upset condition was avoided. As a matter of fact, winter 1978-79 performance appeared equal to or better than any other previous winter. These data indicate that the nutrient program changes have helped avoid winter upset. However, only time and experience over several successive future winters will increase the certainty that winter upset within the primary and secondary system has been controlled. As previously noted, permanent control of winter upset within the primary and secondary systems is a mandatory prerequisite for system recycle. This and other problems related to requirements for recycle will be discussed in further detail in Chapter VI of this report.

In addition to the changes in nutrients previously note, modifications were made to the inlets and outlets of the secondary clarifiers.

TABLE 5.3 NUTRIENT SUPPLEMENTATION SCHEDULE

DATE	GPD OF NUTRIENT* FEED	SECONDARY EFFLUENT LEVEL		
		TOTAL P mg/l	NO_3^- mg/l	NH_3 mg/l
February 9, 1978	5	0.6	0.10	1.5
March 1, 1978	10	0.7	0.15	1.8
March 28, 1978	15	1.0	0.20	2.0

TYPICAL NUTRIENT SUPPLEMENTATION

Final schedule based upon maintenance of 1.0 mg/l total P and 2.0 mg/l NH_3** in secondary effluent.

*Nutrient Feed: A 9% (W/W) Solution of PO_4^{-3}

A 24% W/W Solution of NH_3

**2.0 mg/l NH_3 in secondary effluent resulting in 1.6 mg/l in tertiary effluent discharge as specified by NPDES permit.

These modifications consisted of distributing the clarifier influent evenly over the entire width of the tank to improve plug flow and installation of target baffles to dissipate inlet energy and thus provide a greater area for quiescent settling. Additionally greater weir length was provided for each secondary clarifier outlet to minimize suspended solids carry-over.

As a result of the biokinetic studies, it was decided that a sludge age of approximately 15 days was optimum for summer operation and approximately 30 days was optimum for winter operation of the secondary system. Since the overall waste treatment system is relatively small, it was believed that better, more accurate, control of sludge age could be obtained by direct mixed liquor wastage from the aerator rather than through sludge wastage from the return-sludge line. In addition, sludge age would be relatively independent of sludge concentration. Thus, a variable speed positive displacement pump was installed in the spring of 1978 when sludge age control through wastage from the aeration tanks was adopted. These improvements have allowed accurate control of sludge age. Control is achieved by pumping between five to twenty gpm of sludge from the aeration tanks. The wasted sludge is returned to the aerated equalization tanks, which in effect gives additional degradation of incoming waste materials, acting as a roughing biological pretreatment unit. The sludge is eventually removed along with raw sludge in primary clarifiers and is then pumped to aerated digestor.

V.4 OPERATIONS AND CONTROL SUMMARY

As part of the final activity related to the grant, a complete manual was generated to aid operations for the proper control of the primary and secondary systems. A summary of these operational procedures is presented in Appendix B of this report. It also contains detailed descriptions of all primary and secondary waste treatment water processes.

CHAPTER VI

DESCRIPTION, START-UP, AND OPERATION OF THE ADVANCED WASTE TREATMENT AND RECYCLE SYSTEMS

VI.1 SYSTEM DESCRIPTION

A schematic diagram of the advanced wastewater treatment system as designed is illustrated in Figure 6.1.

The facility includes three major unit processes: sand filtration, activated carbon adsorption, and chlorination. Other facilities included in the system, which are pertinent to wastewater reclaim, include: off specification basin, distribution tank and recycle supply pumps, and reclaimed wastewater storage basin. It should be noted that certain differences exist between the design presented in the Preliminary Engineering Report (1) and the final design as presented in this report. Thus, the final design and operation of the system will be presented and contrasted to the preliminary design in this chapter.

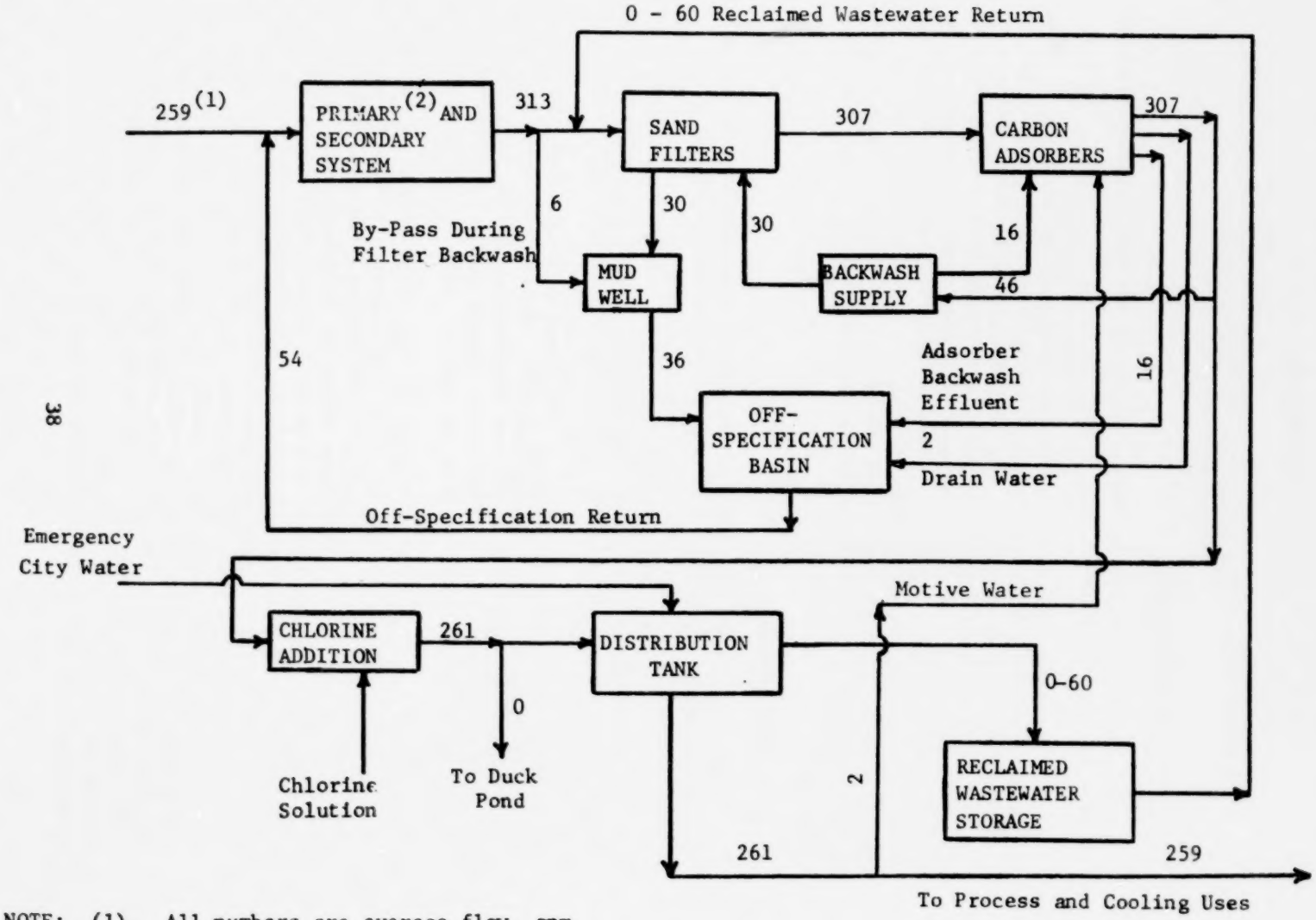
VI.1.1 SAND FILTRATION

Sand filtration is employed to remove suspended solids remaining in the secondary clarifier effluent of the existing facility. The effectiveness of this process is especially important for two major reasons: (1) the effluent eventually enters the plant process and cooling systems in production areas, and (2) high suspended solids levels impair the operation of the carbon adsorption system.

Sand filters were originally evaluated in Phase I of the Grant in both upflow and downflow configurations. These pilot test data were fully documented in the Preliminary Engineering Report (1). At that time, downflow pressure filters operating at 4 gpm/ft^2 were recommended. Filters were to be backwashed at 20 gpm/ft^2 with 5 cfm/ft^2 air scour.

Upon cost effective evaluation during later stages of design, it was decided that single and/or multi-media pressure filters would be cost prohibitive. Several design alternatives became apparent: one being upflow sand filters and the other being an innovative gravity fed single media-automatic intermittent air scoured filter. Even though pilot data indicated that the upflow sand filter could produce acceptable solids removal efficiencies, past experiences indicated that positive control of suspended solids breakthrough would be difficult, if not impossible. If suspended solids would periodically break through the filter, it was feared that carbon adsorbers would be routinely plugged and fouled. In other words, depth filtration was desired from a filtration process efficiency; however, the low probability of solids breakthrough feature common to surface filtration was a must, (i.e., surface filtration filters will usually plug and/or blind providing prohibitive flows and head loss

FIGURE 6.1 WASTE TREATMENT SYSTEM DESIGN



NOTE: (1) All numbers are average flow, gpm

(2) Primary system includes five parellel clarifiers

prior to suspended solids breakthrough). Thus, another alternative, a uniform bed sand filter utilizing automatic intermittent hydraulic and air scour to redistribute accumulated solids was selected. Two 68 square feet filter cells were designed for an average hydraulic flux of 2.5 gpm/ft^2 with a maximum of 4 gpm/ft^2. Design criteria for suspended solids included a maximum of 25 mg/l for influent water and filtered effluent not to exceed 5 mg/l. In addition, the final filtrate was specified to contain not more than 2 mg/l suspended solids when the influent contained less than 10 mg/l suspended solids.

During a typical filter cycle, secondary effluent enters the filter cell through proportioning weirs. The effluent cascades to a wash water trough and is distributed by a trough to V-notch weirs. The effluent flows out through the V-notch weirs, impinging on a splash plate, and then to the filter media surface. As the effluent reaches the filter media surface, all but the very fine particles are retained on the surface of the quartz sand media have an effective size of 0.45 mm and a 1.5 uniformity. Fine particles enter the interstices and are trapped in the media. In time, large particles may completely cover the filter media surface, causing the liquid level to rise over the media surface.

A rising liquid level actuates an air mix system, causing low pressure air to be distributed to a tubular air diffuser. Fine air bubbles leaving the diffuser create a gentle rolling motion over the filter surface. This gentle rolling motion over the filter surface entrains the large particles previously trapped on the filter surface and holds these particles in suspension allowing for continued filtering with minimal head loss accumulation. Depending upon the amount of solids trapped on the filter surface, this action may cause the liquid level to drop in the cell.

The incoming and previously collected suspended solids eventually create higher head losses and in time the liquid level (headloss) will rise to a point at which a pulse mix is energized. The pulse mix system immediately closes the underdrain outlet valve, trapping atmospheric air in the underdrain, and simultaneously energizes the backwash pump. The backwash pump causes the liquid level to rise in the underdrain. This rising liquid, acting as a piston, compresses the previously trapped air which now passes up through the media to the surface, dislodging particles previously trapped in the interstices. These solids expelled from the interstices are now entrained in the gently moving admixture above the media surface.

After 20 to 30 seconds, the pulse mix is terminated and the backwash pump shuts down. The admixture level over the filter media surface drops because the particles previously trapped in the upper interstices of the filter media have been driven out. The previously described air mix system then keeps these particles in suspension above the media rather than immeshed in the media, thus extending

the filter run.

After a period of time, fine particles will again be trapped in the interstices of the filter media, causing the liquid level (headloss) to rise, energizing the pulse mix system and repeating the procedure previously described. Three (3) to five(5) pulse mix cycles are used prior to a major backwash. The frequency and duration of the pulse mix cycles can be varied, depending upon the quality of the secondary effluent. There are two options for energizing the pulse mix system, which are based either on the quality of the secondary effluent, a manual option, or on the liquid level in the filter cell, an automatic option.

In time the pulse mix system register reaches the pre-set number of pulses and is deactivated. The admixture level rises in the filter cell to the point of maximum head loss and the backwash pump is energized. The backwash trough outlet valve opens automatically permitting the mixture of high solids to drain over the wash water trough into the mudwell. Drain period is automatically controlled by an adjustable timer. The air diffuser stays on during this sequence and the subsequent backwash cycle, functioning as an air wash mechanism.

Each cell is backwashed for 3 to 5 minutes at a flux of approximately 12 gpm/ft^2. Both cells cannot be backwashed simultaneously. During backwashing of a cell, incoming wastewater to this cell is collected with the spent filter backwash volume. Thus, during a cell backwash, approximately only one-half of the secondary effluent feed is processed. Spent backwash and unfiltered feed are diverted to a 9000 gallon capacity mudwell and pumped to the 1.5 million gallon off-specification basin for return to the equalization basin for further processing through the primary and secondary system. Filtered water continues to drain through the filter underdrain system to a 12,000 gallon clear well.

The clear well serves as a wet well for pumps to feed the carbon adsorbers.

VI.1.2 CARBON ADSORPTION

The carbon adsorption system contains three pressurized fixed bed carbon adsorbing columns. The column tanks are filament wound glass fiber reinforced polyester tanks equipped with appropriate inlet, outlet, and backwash hardware, capable of working pressures between 55 psig pressure and 1 psig vacuum. The columns were designed to withstand these pressures on either or both sides of underdrain media support plates. Each column has a cross sectional surface area of 78.5 ft.^{2}, a depth of 10 feet, and contains approximately 200,000 lbs. of activated carbon. The design allows for two columns to operate at any given time while the third column is a standby.

Activated carbon adsorbs materials either from liquids or gases because it has a highly porous structure. Each carbon granule contains a vast interconnecting pore network of various sizes. The smaller pores

are nearly the same size as the molecules being adsorbed. This great porosity provides a very large surface area for adsorbing molecules and hence a very large adsorptive capacity. Almost always, adsorption onto activated carbon is a result of Van der Waals, or dispersion forces. These forces exist among all molecules or atoms whether or not they are chemically combined and are related to the forces responsible for condensation or liquefaction of vapors. Generally, molecules of higher molecular weight are attracted more strongly by carbon than lower weight molecules. Hence, activated carbons have a preference for high molecular weight substances, provided they are small enough to enter the carbon pore structure. Additionally, activated carbon prefers non-polar substances. Thus, quite importantly, there is an affinity for the adsorption of non-polar organic molecules from polar solvents such as water. Thus, activated carbon is especially effective in removing dissolved organic pollutants from water.

An important concept in the design of granular activated carbon processes is the adsorption column breakthrough curve. If a solution containing an adsorbable substance passes through a granular activated carbon bed or column, a plot of adsorbable substance concentration in the effluent versus the solution volume passed through yields a breakthrough curve. The adsorbing operation of the fixed bed system can be based on the concept that at breakthrough through the lead column of two series operating columns, the column farthest upstream, is taken out of service. The lag column which is partially loaded to capacity is then placed into the lead position and a fresh column is placed into service as the lag column at the downstream end of the series. In this so-called "flip-flop" operation, the carbon taken out of service is in nearly complete equilibrium or saturation with the incoming stream. Thus, the adsorptive capacity is more fully utilized, reducing the quantity of carbon to be replaced or regenerated as compared to a single fixed bed system. This type of operation improves the economics, especially for high pollution loads. When the adsorptive capacity of the carbon in the lead adsorber is reached and that adsorber is taken out of service, as discussed above, the "spent" carbon is then hydraulically conveyed to the spent carbon tank, constructed similar to the aforementioned fiberglas carbon vessels.

Upon economic appraisal of carbon regeneration, it became apparent that on-site regeneration would be more costly than carbon services purchase through major supply vendors. Thus, fresh carbon is transported to the plant by bulk trailer, where it is hydraulically transferred into the empty carbon adsorber vessel. After the transfer, the used carbon contained in the spent carbon tank is hydraulically conveyed to the empty bulk trailer for transport back to the vendor's regional off-site thermal regeneration facility.

All design criteria were based upon extensive bench and pilot scale treatability studies outlined in the Preliminary Engineering Report (1). The design hydraulic flux for the carbon columns arranged in series was 4.5 gpm/ft^2, based upon average flows. This

loading provided in average carbon contact period of 33 minutes, since two series adsorber vessels, each 10 ft. diameter x 10 ft. deep were to be used. Organic carbon removal efficiencies were planned at approximately 50% based upon 34 mg/l TOC influent and 17 mg/l TOC contained in the effluent. Average design conditions also provided for 667 lbs. of carbon to be exhausted per day which would provide an average carbon replenishment need of one carbon adsorber vessel recharge, 20,000 pounds, every 30 days.

Every two to three days, with a maximum of once per day, the on-line series carbon adsorbers can be backwashed in parallel with reclaim water at a flux of approximately 15 gpm/ft^2 for 20 minutes. Spent backwash water is collected in a 1.5 million gallon capacity off-specification basin for eventual return to the equalization basin for further processing through the primary and secondary system.

VI.1.3 DISINFECTION

The chlorination system was designed to provide disinfection of treated industrial wastewater prior to reuse within the production facilities. Carbon adsorber effluent flows by gravity to a 1920 gallon capacity chlorine flash mix tank to allow a contact period of approximately 6 to 7 minutes, based upon average flow. Gaseous chlorine, fed from one ton storage cylinders into a recycled water stream, is then mixed with carbon adsorber effluent prior to the flash mix tank. In the flash mix tank the chlorine solution and treated wastewater intermix. The mixture is pumped to the 190,000 gallon capacity distribution tank for further contact and disinfection. The distribution tank provides a hydraulic retention period of approximately 10 to 11 hours during average recycle flow rates. Treated water containing a free chlorine residual is supplied to plant manufacturing areas by high pressure centrifugal pumps. The pH of carbon adsorber effluent should be between 6 and 7, slightly acidic, such that most of the free chlorine is in the form of HOCl which is about 40 to 80 times more effective for disinfection than OCl. With the free ammonia level in the range of 0.5 to 1 mg/l, and an average organic chlorine demand of 1 to 2 mg/l chlorine, the total chlorine demand through the system ranges from 2.5 to 5 mg/l. Thus, between 3.5 and 6mg/l chlorine can be routinely supplied through the system.

VI.2 HYDRAULIC CONSIDERATIONS FOR DESIGN OF THE ADVANCED WASTE TREATMENT SYSTEM

The design flow for the advanced wastewater treatment system was set at 285 gpm in the Preliminary Engineering Report (1). This figure was determined through anticipation of an average 205 gpm net discharge of wastewater from the manufacturing facility. A correction of anticipated values by 10% to accommodate flow measurement inaccuracy, and a need to handle an additional 54.3 gpm of water during the summer months, which was stored in the reclaimed water storage basin during winter months, would produce (205 gpm + 54.3 gpm) 110% or 285 gpm flow

which was allowed for in the preliminary design of the advanced waste treatment system. The flow of 59 gpm of stored reclaimed water was to be processed only through the advanced waste treatment system.

In the preliminary design, it was anticipated that sand filter backwash and activated carbon backwash would amount to 43,120 gpd and 47,120 gpd, respectively. These sources would produce an average discharge of 30 gpm, respectively and should have been included into the design flow rate for the AWT system, since they were planned for recycle back through the treatment process. Upon final design, these backwash flows were included into the hydraulic design; thus, the primary and secondary system was planned to be hydraulically loaded at approximately 327 gpm. This flow was arrived at by considering 226 gpm waste water flow from manufacturing (with all originally conceived "piggyback systems"), an additional 33 gpm of manufacturing waste water generated by segregation of "piggyback" systems (see Table 4.4 and Section VI.3.4 and VI.3.5), and an additional 68 gpm wastewater flow spent advanced waste treatment backwashing operations and waste treatment cleaning, carbon transport and general operations. The effects of this hydraulic flow of 337 gpm through the primary and secondary treatment system were not considered to be unreasonable. Review of past operational data summarized previously in Table 5.1 indicated that the primary and secondary system had the necessary hydraulic flow capacity of 300 to 330 gpm. Latter sections in this chapter will address hydraulic effects of the advanced waste treatment system upon the primary and secondary treatment systems. It is also noted that during the operational performance over the five month period in 1976, waste character as previously presented in Table 5.2 was that which was expected during operation of the recycle system.

Finally, it should be noted that the raw waste composition observed during the early pilot trails, 1973, see Table 5.2, was also expected to be representative of the waste at the time of recycle system operation. However, waste composition did not remain constant, shifting more towards PVA's and epoxy's with fewer starch materials.

VI.3 SYSTEM START UP

The major units of the advanced treatment system, filtration, carbon adsorption and chlorination, began operation in October 1977. At this time sanitary segregation was not completed. Thus, between October 1977 and March 1978 combined sanitary and industrial wastes were treated through the advanced treatment system and discharged. It is important to note that a definite prerequisite, based upon potential health hazards, for recycle was the removal of all sanitary wastes from the industrial waste collection system. During March 1978, the segregated sanitary waste collection and treatment system became operative. Between March 1978 and April 1978, biological studies were performed to assess viral and bacterial contamination of segregated industrial wastes. These studies began after a minimum of three weeks

of continuous operation of the entire industrial waste treatment system, (i.e., primary, secondary, and advanced).

VI.3.1 BIOLOGICAL QUALITY OF SEGREGATED INDUSTRIAL WASTE WATER

Totally free of sanitary-domestic discharges, it was believed that the three week period of time would allow the treatment system to be purged of any residual pathogenic organisms that would enter the proposed recycle system through sanitary waste collection systems. Thus, a nationally recognized consultant specializing in virus and bacterial evaluations was contracted to perform the evaluation. Virus sampling was performed during the week of April 17, 1978 and bacterial sampling was performed during the week of April 26, 1978. The procedures used for sampling and analysis were similar to those outlined in Standard Methods for the Analysis of Water and Wastewater (6). A detailed description of the procedures used is presented in Appendix C.

Results of the virual plaque assay on primary rhesus monkey kidney cells and HeLa cells for a wastewater sample along with those of a control tissue culture plate are provided in Table 6.1 and 6.2. These results indicated no plaques on HeLa cells for the wastewater sample or the control. Plaques were found on the primary rhesus monkey kidney cell (PMK), see Table 6.1. These PMK plaques are of Simian origin due to a foamy type virus which is indigenous to the animals and frequently found in PMK cells. In summary, no virus plaques related to the wastewater sample were recovered in either primary rhesus monkey or HeLa cell cultures.

Results of the field efficiency run are provided in Tables 6.3 and 6.4. The stock virus solution was found to contain 2.5×10^2 plaque forming units (PFU)/ml on PMK cells and 3.03×10^2 PFU/ml on HeLa cells. Assay of the process wastewater, which was seeded with the stock virus solution, provided a total virus recovery of 4.5×10^4 PFU/ml on PMK and 3.26×10^2 PFU/ml on HeLa cells. The range and efficiency of recovery between 9% and 53% was not a result of variation in the field concentration procedure, but was a result of tissue culture response to the virus during laboratory incubation. It was believed that the titration performance of the HeLa cell cultures was doubtful and they were repeated to eliminate the possibility of a technical error during the inoculation. Thus, HeLa cell efficiency was found to be incorrect and the 9% efficiency as found on PMK was accepted as the efficiency of recovery and is a value typically found in waters of industrial origin with complex organic constituents.

Results of the bacterial testing are provided in Table 6.5. No fecal coliforms or fecal streptococci were found in sample sizes of up to 250 ml. Total plate counts were found to range between 2,650 cells/liter and 4,450 cells/liter depending on the technique and medium utilized. Obligate aerobes, facultative organisms, and obligate anaerobes were found in wastewater samples as well as staphylococcus.

TABLE 6.1

PLAQUE ASSAY OF WASTE SAMPLE IN PRIMARY

RHESUS MONKEY KIDNEY TISSUE CULTURE

WASTEWATER SAMPLE *

Plate	Number of Plaques	Virus Identification
1	0	----
2	2	2 Simian foamy type
3	3	3 Simian foamy type
4	0	----
5	0	----
6	2	1 Simian foamy type 1 passed to new cell culture (on test)
7	0	----
8	0	----
9	1	1 passed to new cell culture (Simian foamy type)
10	0	----

CONTROL **

Plate	Number of Plaques	Virus Identification
1	1	1 Simian foamy type
2	3	3 Simian foamy type
3	2	2 Simian foamy type

* 0.4 ml/plate of undiluted sample

** 0.4 ml/plate of tryptose phosphate broth

TABLE 6.2

PLAQUE ASSAY OF WASTEWATER SAMPLE IN

HeLa CELL CULTURE

WASTEWATER SAMPLE *		CONTROL **	
Plate	Number of Plaques	Plate	Number of Plaques
1	0	1	0
2	0	2	0
3	0	3	0
4	0		
5	0		
6	0		
7	0		
8	0		
9	0		
10	0		

* 0.4 ml/plate of undiluted sample

** 0.4 ml/plate of tryptose phosphate broth

TABLE 6.3

PLAQUE ASSAY OF STOCK VIRUS SOLUTION AND VIRUS - SEEDED WASTEWATER IN HeLa CELL CULTURE

STOCK VIRUS SOLUTION

Dilution	No. Plaques Plate 1	No. Plaques Plate 2	No. Plaques Plate 3	No. Plaques Average	PFU/ml	Average PFU/ml
0.2 ml/plate undiluted	19	19	7	13.33	$.66 \times 10^2$	--
10^1	4	3	No Test	3.50	1.75×10^2	--
10^2	1	3	0	1.33	6.67×10^2	*
10^3	0	0	0	0	--	3.03×10^2
10^4	0	0	0	0	--	--

VIRUS-SEEDED WASTEWATER

Dilution	No. Plaques Plate 1	No. Plaques Plate 2	No. Plaques Plate 3	No. Plaques Average	PFU/ml	Average PFU/ml
0.2 ml/plate undiluted	12	13	No Test	12.50	$.625 \times 10^2$	--
10^1	4	6	5	5.00	2.50×10^2	--
10^2	3	1	0	1.33	6.65×10^2	*
10^3	0	0	0	--	--	3.26×10^2

*Stock and seed virus titrations on test for verification of recovery.

TABLE 6.4

PLAQUE ASSAY OF STOCK VIRUS SOLUTION AND VIRUS-SEEDED WASTEWATER IN PRIMARY RHESUS MONKEY KIDNEY TISSUE CULTURE

STOCK VIRUS SOLUTION

Dilution	No. Plaques Plate 1	No. Plaques Plate 2	No. Plaques Plate 3	No. Plaques Average	PFU/ml
0.2 ml/plate undiluted	Total CPE *	Total CPE	Total CPE	--	--
10^1	TNTC **	TNTC	TNTC	--	--
10^2	TNTC	TNTC	TNTC	--	--
10^3	TNTC	TNTC	TNTC	--	--
10^4	6	7	2	5	2.5×10^5

VIRUS-SEEDED WASTEWATER

Dilution	No. Plaques Plate 1	No. Plaques Plate 2	No. Plaques Plate 3	No. Plaques Average	PFU/ml
0.2 ml/plate undiluted	Total CPE	Total CPE	Total CPE	--	--
10^1	TNTC	TNTC	TNTC	--	--
10^2	TNTC	TNTC	TNTC	--	--
10^3	5	17	5	9	4.5×10^4

* Cytopathic effect

** Too numerous to count (or very large and plaques ran together)

TABLE 6.5

BACTERIAL TESTING RESULTS

TEST	ORGANISM CONCENTRATION (cells/liter)
Total Plate Count (membrance filter technique)	2650
Fecal Streptococcus	0
Staphylococcus	3.5
Fecal Coliform	0
Obligate Aerobes (nutrient agar - pour-plate technique)	(total areobes - total faculatative) 1550
Facultative Organisms	1950
Obligate Anaerobes	(total anaerobes - total facultative) 950
Total Bacterial Count (nutrient agar - pour-plate technique)	4450

None of the concentrations were in a range that would cause health concerns for nonpotable use of this water in industrial applications.

In summary, it was concluded that virus, fecal streptococcus and coliforms, and staphylococcus levels were so low that it was not anticipated that these organisms would cause health problems within the reuse system. Furthermore, similar conclusions were obtained pertinent to broad general classifications of bacteria as obligate aerobes, facultative organisms, and obligate anaerobes. Thus, these results indicated that biologically, the finished water would be acceptable for a reclaim supply.

VI.3.2 LOW & HIGH QUALITY RECYCLE SYSTEMS

The recycle scheme, as previously discussed in Chapter IV, described that reclaimed wastewater would be supplied to plant process cooling systems and plant process cleaning and washdown operations. These potential demand areas were classified into two groups: cooling system-high quality demands and washdown operation - low quality demands.

Beginning on April 16, 1978, isolated low quality demand areas were brought "on-line" with reclaimed wastewater. The program was to gradually increase recycle systems systematically by adding more and more low quality water demanding areas into the recycle system.

High quality water demanding areas of process cooling were avoided until pilot cooling loops similar to those used and documented in the Preliminary Engineering Report (1) were operated on reclaim water. The pilot cooling trials using reclaim water were conducted from June through July 1978. The pilot evaluation of the effects of reclaim water upon the high quality demanding process cooling systems indicated no significantly different results than those obtained and documented in the pilot cooling studies outlined in great detail in the Preliminary Engineering Report (1). With a successful outlook, high quality water demanding process cooling systems were systematically connected to the recycle system one by one beginning with the smallest and ending with the largest during July 1978.

A historical graphical presentation of the average weekly hydraulic flows: wastewater processed, wastewater discharge and treated wastewater recycled is presented in Figure 6.2. In summary, the important events were:

(1) March 1978 sanitary segregation with total discharge;

(2) April 16, 1978 beginning of low quality demand recycle:

(3) The end of July 1978, the beginning of high quality demand recycle.

As can be seen in the figure, sanitary segretation did create a measurable reduction in wastewater discharge. Between January 1, 1978 and March 11, 1978, the weekly average wastewater flow was 0.382 mgd. During this period combined sanitary and industrial wastes were treated through the advanced waste treatment system and discharged. Between March 11, 1978 and April 15, 1978, the weekly average flow was 0.332 mgd. Thus, sanitary segregation accounted for an average flow reduction of approximately 0.05 mgd, as expected.

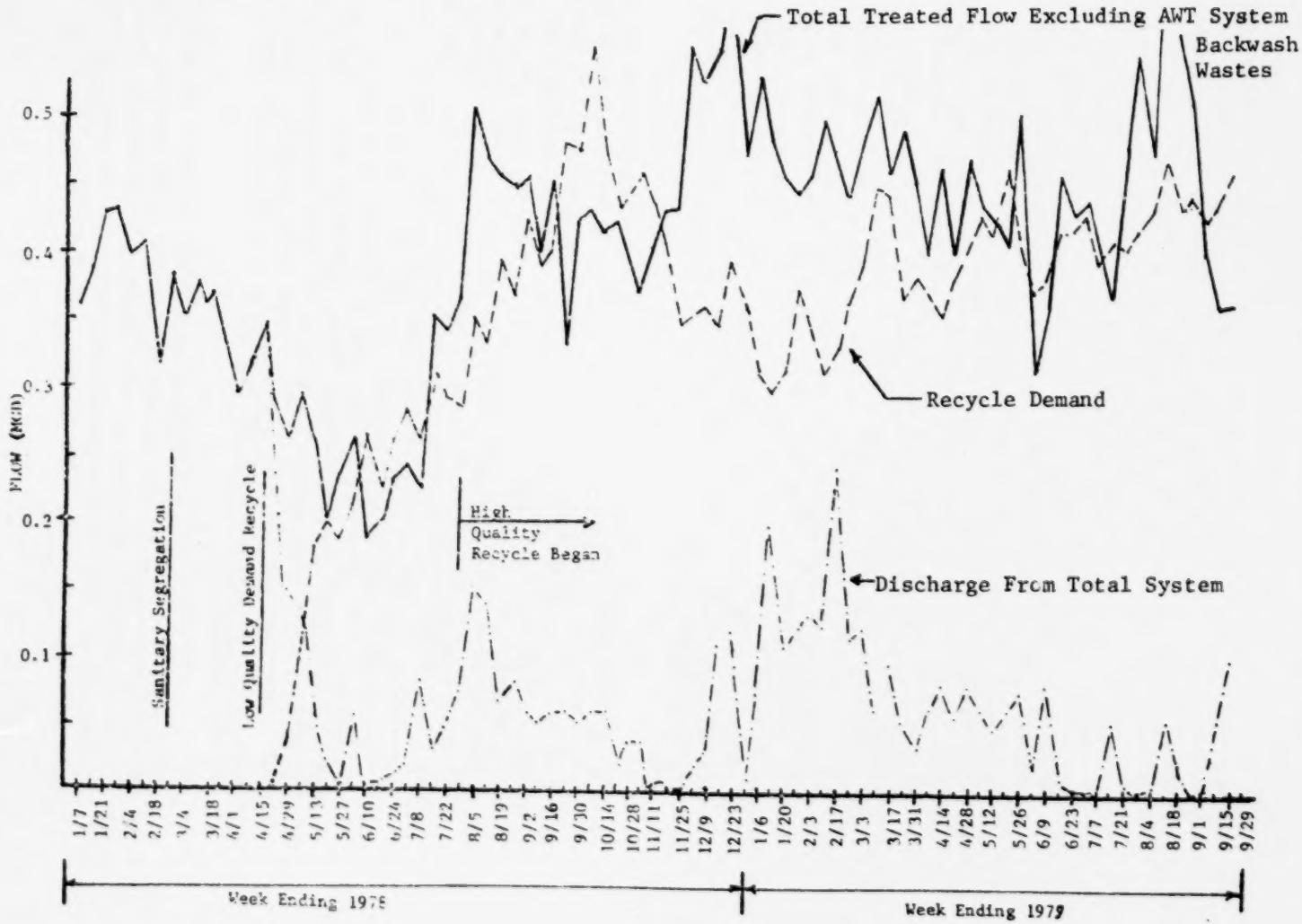
VI.3.3 SUPPLY SYSTEM HYDRAULIC PROBLEMS

On April 15, 1978, low quality recycle began. As illustrated in Figure 6.2, the recycle flows increased as each low quality demand was incorporated in the system. During July and August, high quality demand addition to the system produced a continued increase in recycle flow. It is noted that discharge dramatically dropped during the initial recycle startup. However, periods of time have existed when the average daily total treated water flow has been in excess of the recycle demand; e.g., see periods 7/8/78 - 9/16/78 and 11/18/78 - 5/12/79. This condition creates surplus wastes within the system which must be stored and/or discharged. If water is stored in the reclaim storage pond, it must be reprocessed through the AWT system prior to use in the reclaim system, see Figure 6.1. If waste water flows are high, use of stored reclaim water to supply peak "instantaneous" recycle demands can hydraulically overload the AWT system. Thus, during these periods fresh water makeup was used to supply peak "instantaneous" demands.

It is important to note that wastewater processed flows do not necessarily equal the sum of recycled water flow and discharged wastewater flow. This inequality is due to the addition of fresh water into the system at the recycle distribution tank to maintain an adequate supply to the plant. As previously stated, periods of time have existed when the treatment system count not process wastewater and/or stored reclaim water at high enough flow rates to satisfy demand flow rates. This problem of hydraulic balance has been due to several factors; some of which have been easily corrected and others which are presently being evaluated. By the end of July, after all major high quality demands were on line in the recycle system, it became apparent that the system was being hydraulically overloaded with fresh makeup water at the distribution tank, see Figure 6.1. Much of this overload was created by large peak demands. It is noted that all flows represented in Figure 6.2 are weekly averages of average daily flows.

The supply system was equipped with pumps capable of delivering 70 to 80 psi pressure at all points within the distribution system. The 70 to 80 psi was designed to aid cleaning in washdown operations and to encourage use, from a psychological point of view, of reclaim water within the manufacturing plant. Daily results indicated that,

FIGURE 6.2 AVERAGE WEEKLY FLOW IN RECYCLE SYSTEM



not only was reclaim supply used, but the high energy condition of 70 to 80 psi also increased instantaneous flow demands such that significant volumetric deficiencies existed in the distribution tank. Since the volume of the distribution tank supply was relatively fixed, it was decided to reduce the pressure head by approximately 40% down to 40 to 50 psi within the plant. This was accomplished by reducing the speed of the belt driven supply pumps.

The effect of supply pressure reduction on lowering the overall demand of recycle water can be seen in Figure 6.2, beginning at the end of September 1978. Not only was the average daily demand for recycle reduced by approximately 0.1 mgd, but also peak demands were considerably reduced.

VI.3.4 INERT GAS SCRUBBER RECYCLE PROBLEMS

During August and September of 1978, a hydraulic audit was done to identify other unplanned sources of fresh water additon to the recycle system. Upon inspection, it was found that the inert gas scrubber was not connected to the mat line in a "piggyback" fashion as planned and documented in the Preliminary Engineering Report (1), in order to minimize distribution piping. However, the scrubber and the mat line were both operating on recycle water at approximately 40 to 30 gpm, respectively. By November 1978 it became apparent that the reclaim supply pressure to the inert gas scrubber was too low. Thus, the scrubber was operated on fresh water for an interim time period until March 1979 and during the February hydraulic audit, when appropriate modulation valving was received and installed. Presently, no problems related to the use of reclaim water in the inert gas scrubber have been observed.

As an added advantage, utilization of reclaim water as feed for the inert gas scrubber eliminates approximately 37 gpm of fresh water addition into the overall system. As such, the average design discharge during winter becomes less than the minimum design recycle demand, see Tables 4.3 & 4.4 and Figure 4.2. This is highly desirable since the 1.5 million gallon reclaim basin should not be needed for winter storage, i.e. the system design is hydraulically balanced during winter and summer months, provided excess fresh water uses are controlled. From a practical point, storage would only be needed to accomodate occasional discharge surges that the reclaim supply tank cannot accomodate.

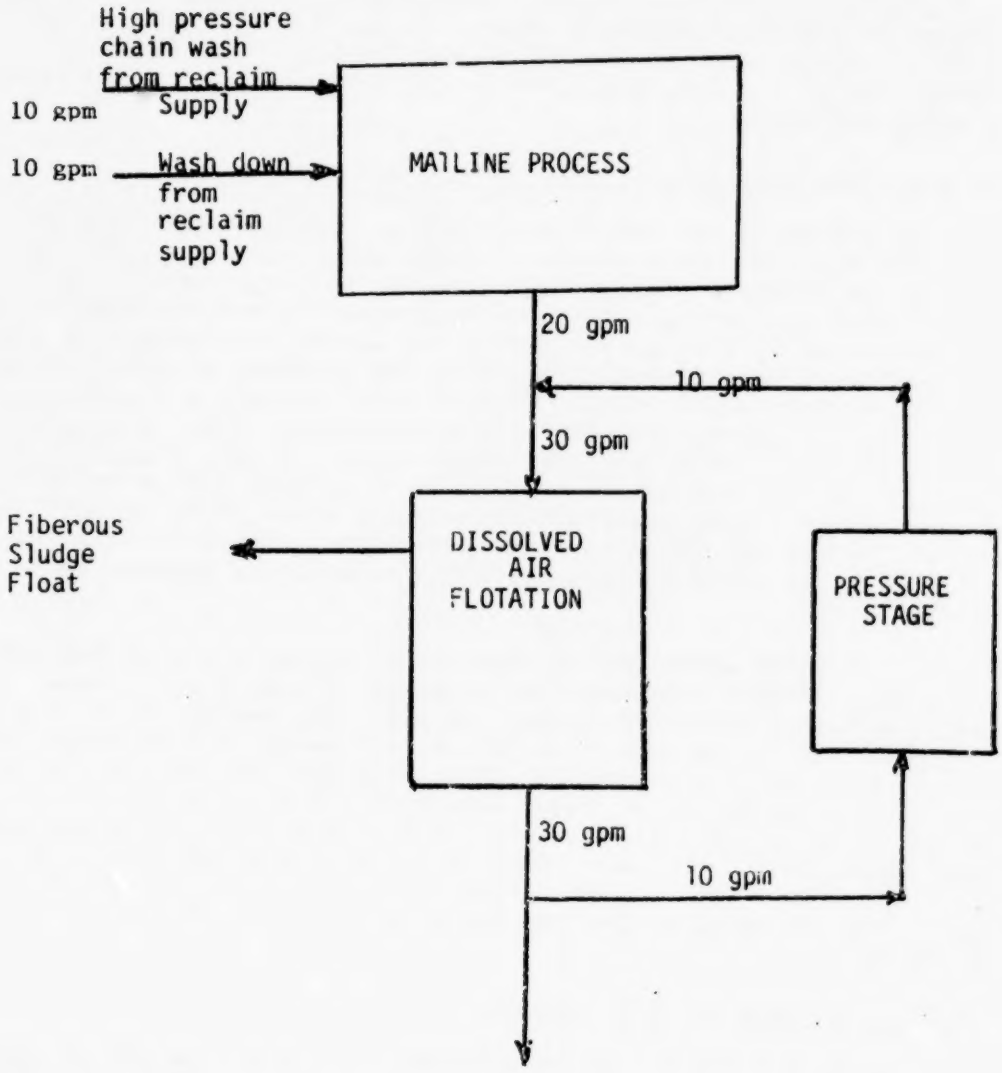
VI.3.5 MAT LINE RECYCLE PROBLEMS

Figure 6.3 illustrates the process flow diagram for the mat line and dissolved air flotation (DAF) system as planned. The high pressure chain wash sprays were to be operated on reclaim water. Wastewater from the mat lines, laden with fibers was to be treated through a dissolved air flotation unit. A pressurized 70 psi, 10 gpm recycle stream was to supply the necessary dissolved air for fiber separation.

FIGURE 6.3

PROPOSED MAILINE RECYCLE SYSTEM

WITHOUT "PIGGYBACK"



Net Effects: 20 gpm Recycle Demand

20 gpm Wastewater Discharge

Fibers Removed

Upon installation and start up in the fall of 1978, although good fiber separation was achieved, the DAF effluent was unacceptable for recycle to the pressurization vessel. Residual fibers caused plugging problems in the DAF eductors. Strainers were installed in the pressure recycle line to attempt residual fiber removal. Although the strainers did improve the operation, intermittent eductor fouling remained. Thus, the system was modified as illustrated in Figure 6.4. Reclaim supply water is currently used for pressurization. Although operational problems have been minimized using this scheme, 20 gpm more are recycled in this area than originally planned.

A major problem was encountered during startup of the mat line processes with reclaim supply water in September 1978. Reclaim supply water created major plugging problems in the high pressure chain wash spray nozzles. After several trials, the high pressure chain wash system was connected back to fresh water. After several months, during the spring of 1979, another attempt was made to bring the spray wash system onto reclaim supply water. Again, nozzle fouling and pluggage was encountered. Thus, spray washes are currently supplied by city water, creating an additional 10 gpm of unplanned fresh water makeup to the overall recycle system.

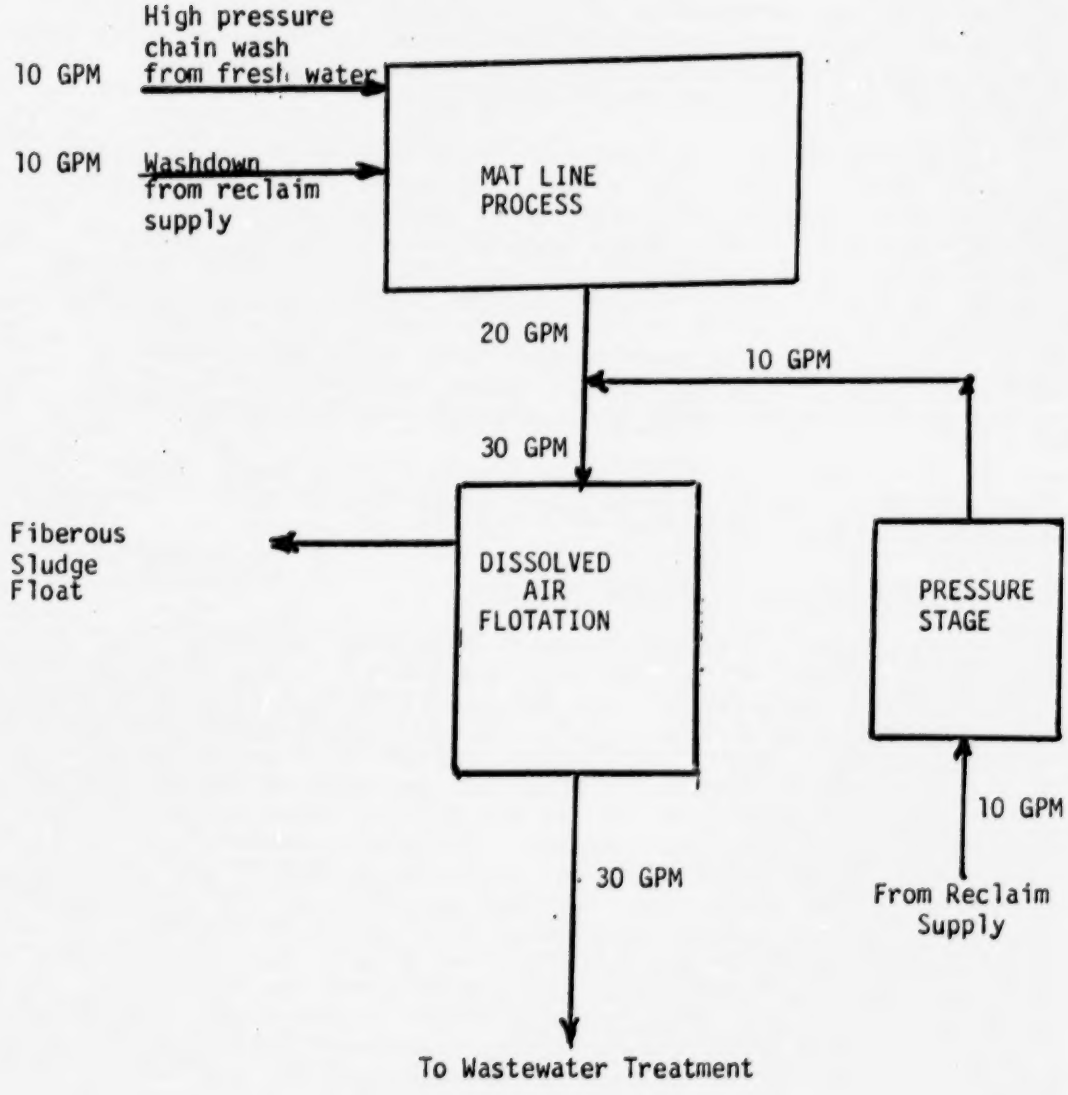
At the time of writing of this report, a third set of trials were made and indicated reclaim water can be used to supply the high pressure mat line wash system.

VI.3.6 OTHER SYSTEM HYDRAULIC PROBLEMS

Results from a detailed hydraulic water audit conducted from February 5 through February 28, 1979, see Table 4.3, 4.4 and Figure 4.2 (a and b), indicated that the raw waste flow rate averaged 361 gpm, which was 40 percent larger than the expected modified design of 259. Furthermore, the recycle flow averaged 270 gpm or 24 percent larger than the average winter reuse flow of 218 gpm expected without system modification as presented in VI.3.4 and VI.3.5. Thus, the recycle flow was 52 gpm larger, with Matline & IG Scrubber separation. (Table 4.4), which would also make the raw waste flow 52 gpm larger than the expected design flow, totaling approximately 257 to 278 gpm. Therefore, the real excess fresh water flow implied is between (361-257) and (361-278) or between 104 and 83 gpm. This extra flow must be extra fresh water entering the system over and above the amount of planned city water input of 73 gpm (Figure 4.2). The additional fresh water flow of 83 to 104 gpm was found to be caused by: leaks in condensate return lines through the plant $\sim$20 gpm; leaky valves throughout the plant $\sim$20 gpm; and the aforementioned recycle problems related to the inert gas scrubber system $\sim$40 gpm during audit, the matline operations $\sim$10 gpm, and $\sim$10 gpm due to miscellaneous washing operations. All of the maintenance related problems are in the process of being corrected. Furthermore, excess fresh water is introduced into the system at the reclaim distribution tank to meet

FIGURE 6.4

MATLINE RECYCLE AS PRESENTLY OPERATED



Net Effects: 20 gpm Recycle Demand
10 gpm Freshwater Intrusion
30 gpm Wastewater Discharge
Fibers Removed

recycle demands, a point that will be later developed in Sections VI.4 and VII.4.

VI.4 OPERATION OF THE ADVANCED WASTE TREATMENT SYSTEM

VI.4.1 SAND FILTRATION

A summary of the performance of the sand filtration process over the 9-month test period appears in Table 6.6. Influent suspended solids monthly average concentrations ranged between 10 mg/l and 55 mg/l. These averages were in the upper range of those anticipated during design. The average hydraulic flux ranged between 2.93 and 3.09 gpm/ft^2, which is also higher than the design average of 2.5 gpm/ft^2, originally expected. The backwash volume expressed ad a percent of processed volume ranged from a monthly average of 8.2 to 16.8 percent. Again, this is slightly larger than the 8 to 12 percent range expected in the design. However, this increase in backwash requirement is consistent with higher hydraulic flux and suspended solids loadings.

During the operation of the filters, effluent quality has been acceptable and has averaged between 2 and 5 mg/l suspended solids. However, during a two-day period in late July 1979, effluent suspended solids rose to over 10 mg/l, which produced biological growth with subsequent anaerobic activity within the downstream carbon adsorbers. During mid-August, this activity resulted in the generation of volatile sulfides which produced objectionable orders within all plant recycle systems. Subsequently, all water recycle systems were purged and the carbon adsorbers recharged and cleaned. The effects of the major system purge which occurred in mid-August can be observed in Figure 6.2. These purges required major demand increases which maximized at 0.678 MGD during the week of August 18, 1979. It is noted that system discharge did not dramatically increase during this period because excess water was stored within the system off-specification basin.

In summary, the filters have operated very well, considering that the applied hydraulic and suspended solids flux levels have been larger than anticipated. Some of these problems have been due to the effects of the tertiary system wastes (i.e., spent sand filter and activated carbon backwash waters) which are recycled back to the entire treatment system via the mudwell and off-specification basin (see Figure 6.1). During the preliminary design, it was estimated that the combination of spent sand filter and activated carbon backwash wastes would account for a continous average flow of 30 gpm and 33 gpm, respectively. In the preliminary design, treatment of these flows were not considered. During the final design these flows were recycled back through the treatment system as indicated in Figure 6.1. The calculated average daily flows for the sand filter backwash only, over the 9-month trial period are tabulated in Table 6.6. These flows ranged from 6 gpm to 195 gpm with an

TABLE 6.6 - SAND FILTER PERFORMANCE SUMMARY

MONTH	SUSPENDED SOLIDS mg/l				SUSPENDED SOLIDS LOAD lb/Day				HYDRAULIC[1] FLUX gpm/ft^2 PROCESSED				BACKWASH VOLUME[1] PERCENT OF PROCESSED				SAND FILTER BACKWASH FLOW RATE gpm (Day)			
	$\bar{X}$ [2]	σ [3]	H[4]	L[5]	$\bar{X}$	σ	H	L	$\bar{X}$	σ	H	L	$\bar{X}$	σ	H	L	$\bar{X}$	σ	H	L
Jan.	21.3	31.4	98	3	93.3	117	372	15	3.02	.40	3.93	2.26	8.22	4.87	23.4	1.49	32.1	19.3	79.9	6.7
Feb.	32	39	104	4	144	174	403	10.5	3.03	.33	3.48	2.21	8.93	4.65	21.5	2.69	35.1	18.9	86.1	12.5
Mar.	12.3	6.3	20	5	57.7	28.5	93.1	24.3	3.09	.42	3.46	1.90	9.82	4.14	21.5	5.21	38.1	11.2	56.7	22.1
Apr. (6)	12.8	8.4	27	5	60.4	45.3	133.6	18.3	2.93	.68	4.28	1.87	12.5	6.03	22.0	4.48	47.3	27.4	107.6	7.93
May (6)	18	10.1	35	5	82.7	53.4	163	21.6	3.11	.53	4.24	1.79	16.8	10.2	56.4	3.3	64.4	35.6	163	11.9
June (7)	54.3	100.9	302	6	227	406	1221	29	3.03	.49	3.77	1.55	15.5	10.8	58	6.3	58	37.7	195	14.2
July (7)	10.6	5.6	18	7	54.1	30.9	107	37.5	3.26	.60	4.53	1.41	15.2	9.5	45.5	3.0	62.7	40.4	181	10.2
Aug.	10.4	9.4	31	2	49.9	43.1	119	9.5	3.08	.60	4.28	2.28	8.78	4.25	16.8	2.68	34.3	15.7	69.7	11.3

(1) Based upon One Carbon Adsorber Backwash per Day
(2) Monthly Mean
(3) Monthly Standard Deviation
(4) Monthly High Value
(5) Monthly Low Value
(6) Filters Temporarily Converted to Dual Media.
(7) Filters with Anthrafilt media only.

overall daily average during the 9-month test period of 46 gpm, which is 16 gpm or 53 percent larger than originally expected for the sand filter alone.

By March 1979, it became apparent that the sand filters were being operated over design conditions (see Section VI.1.1), and more capacity would be needed to meet peak demand flow rates. At that time two alternatives were considered: (1) increasing the size of the filters through addition of another filter cell; or (2) changing filter media to a coarser, more porous, grade or a combination of the existing grade and a new grade (i.e., converting the filters to a modified dual media type).

The second option was selected for evaluation since it would not require a major capital expenditure. Therefore, in early April through May of the test period, filter cells were loaded with a combination of 50 percent design media, .45 mm quartz sand with a 1.5 uniformity, and 50 percent of a 1:1 mixture of anthrafilt having 0.7 mm and 1.5 mm effective sizes. Reference to the performance summary, Table 6.6, during these two months of April and May, no significant improvement in average hydraulic flux was obtained through change of the media, although peak hydraulic flux was improved as indicated by the larger daily deviation and the increase in the monthly high hydraulic flux to 4.28 and 4.24σ, gpm/ft^2.

During the months of June and July, media was again replaced to a single media, anthrafilt, in an attempt to further increase the filter porosity and increase hydraulic flux capacity. Although the average hydraulic flux and peak flux as indicated by σ, and the monthly high flux did increase (see Table 6.6), filter suspended solids breakthrough and resultant loading on the carbon adsorbers produced unacceptable anaerobic odor problems within the adsorbers and the entire recycle system as previously noted. Thus, it was decided that if anthrafilt media was to be used, it could only be used in conjunction with the finer sand media in a dual media configuration. However, since the effects of major suspended solids breakthrough were observed and resulted in major purges of all plant recycle systems, the single media sand was selected for continued use as a precautionary measure.

Throughout the entire period, media has been occasionaly replaced when vigorous and repeated backwashing would not throughly cleanse the sand. Close inspection of the media during these occasions has revealed that the media was relatively clean and rapid headloss accumulation was being caused by a media clumping phenomenon. When media was placed on a flat surface clumps or aggregates of media ranging from 1/32 to 3/32 inch in size would remain as if the media particle were statically charged. When lightly touched, these clumps would fall apart, indicating that the binding forces present were relatively small. Qualitative analysis through UV and IR spectroscopy of solvent extractions of clumped media indicated the presence of chromophoric bodies related to polyester & polyvinyl acetate (PVA) residues that had escaped coagulation

and/or degredation within the primary and secondary treatment systems. Numerous commercial cleaning and/or dispersing agents and also acid and caustic solutions have been tried, with limited success, to prevent media clumping. Currently routine application of a dilute caustic wash, once per week apparently has extended media live from 4 to 6 months. It is important to note that these problems may be intensified with complete loop closure. It is also important to note that although significant clumping has been observed in the sand filter, very little clumping has been observed in the activated carbon absorber. However, carbon is routinely changed every 1½ to 2½ months as it is exhausted, and sand media clumping has usually been observed after 1½ to 2½ months. Thus, these same materials could be coating the carbon surface which may also reduce the absorption rate and/or capacity as the result of a blinding or coating action. Furthermore, the TOC values are also high due to concentrating effects of system closure. These effects will be discussed in a later section. The poor performance of the secondary system is believed to be partially related to the hydraulic overloads produced by wastes generated by the advanced waste treatment system and the raw manufacturing waste.

VI.4.2 CARBON ADSORPTION

A summary of the weekly average performance of the carbon adsorbers over the 9-month evaluation period appears in graphical form in Figures 6.5 and 6.6. These data represent weekly averages of daily total organic carbon and BOD measurements. The percent removal of TOC and BOD by the lead and lag adsorbers, based upon this data, appears in Figures 6.7 and 6.8. The monthly data appears in Table 6.7. Over the entire test period TOC removals averaged 40 percent, based upon secondary effluent TOC feed. This value is below the 50 percent removal designed and expected. However, the average daily influent concentration was 122 mg/l or 3.6 times higher than the expected design level of 33 mg/l TOC. Furthermore, the average hydraulic flux and contact time were 5.3 gpm/ft^2 and 27.6 min., respectively. These values are 17.7 percent higher and 16.3 lower than the anticipated design values of 4.5 gpm/ft^2 and 33 min. Thus, the organic and hydraulic loadings experienced are considerably higher than those expected in the preliminary report and are certainly responsible for the observed decreased removal efficiency. The BOD removals average 49.4% based upon secondary effluent feed. The average daily influent concentration (secondary effluent) was 27 mg/l which was 2.7 times larger than that expected (i.e., 10 mg/l based upon past operation, see Table 5.1). These data indicate that the primary and secondary system performance has decreased since the recycle system became operational.

The operational history for a typical 'flip-flop' bycle for one carbon vessel is presented in Figures 6.9, 6.10 and 6.11. This cycle was taken from the daily operation of a fresh carbon load in the lag position between March 5, 1979 through April 10, 1979 and in the lead position between April 10, 1979 and May 4, 1979. The average hydraulic flux during these time periods were 5.3 gpm/ft^2 and 5.07 gpm/ft^2, approximately the same as

FIGURE 6.5 WEEKLY AVERAGE TOC FOR SECONDARY EFFLUENT, LEAD CARBON COLUMN EFFLUENT, AND LAG CARBON COLUMN EFFLUENT

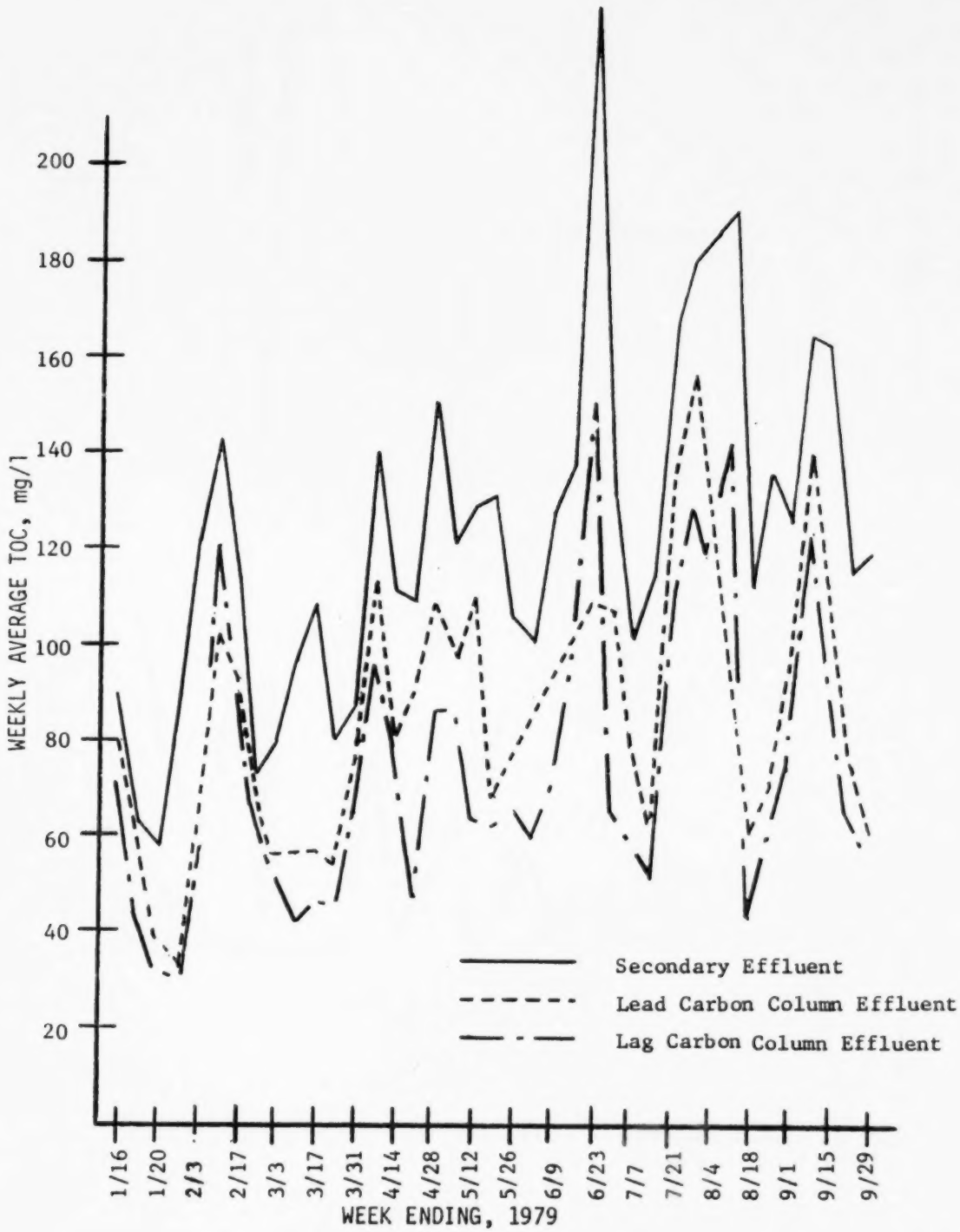


FIGURE 6.6 WEEKLY AVERAGE SECONDARY AND CARBON COLUMN EFFLUENT BOD

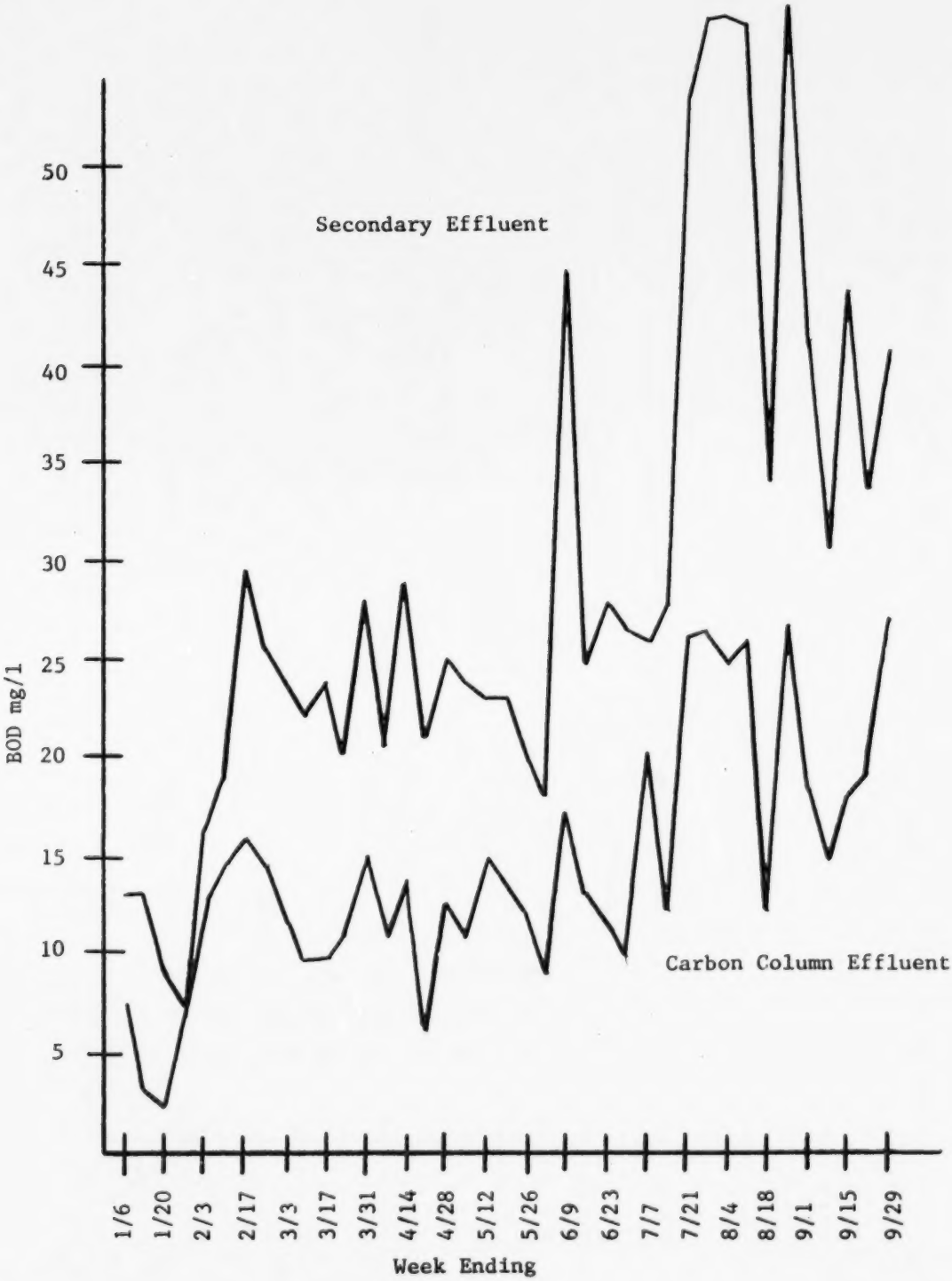


FIGURE 6.7 PERCENT TOC REMOVAL THROUGH CARBON COLUMN SYSTEM

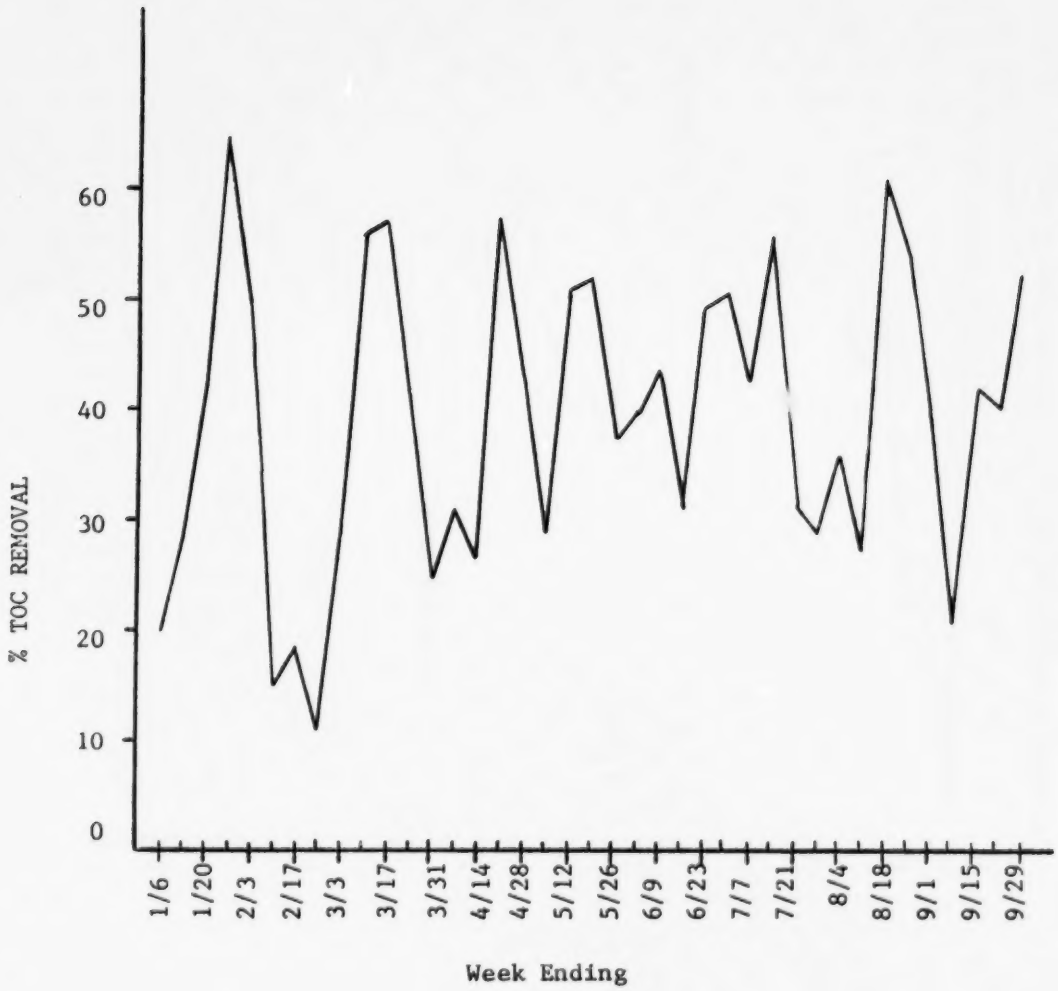


FIGURE 6.8 PERCENT BOD REMOVAL THROUGH CARBON COLUMN SYSTEM

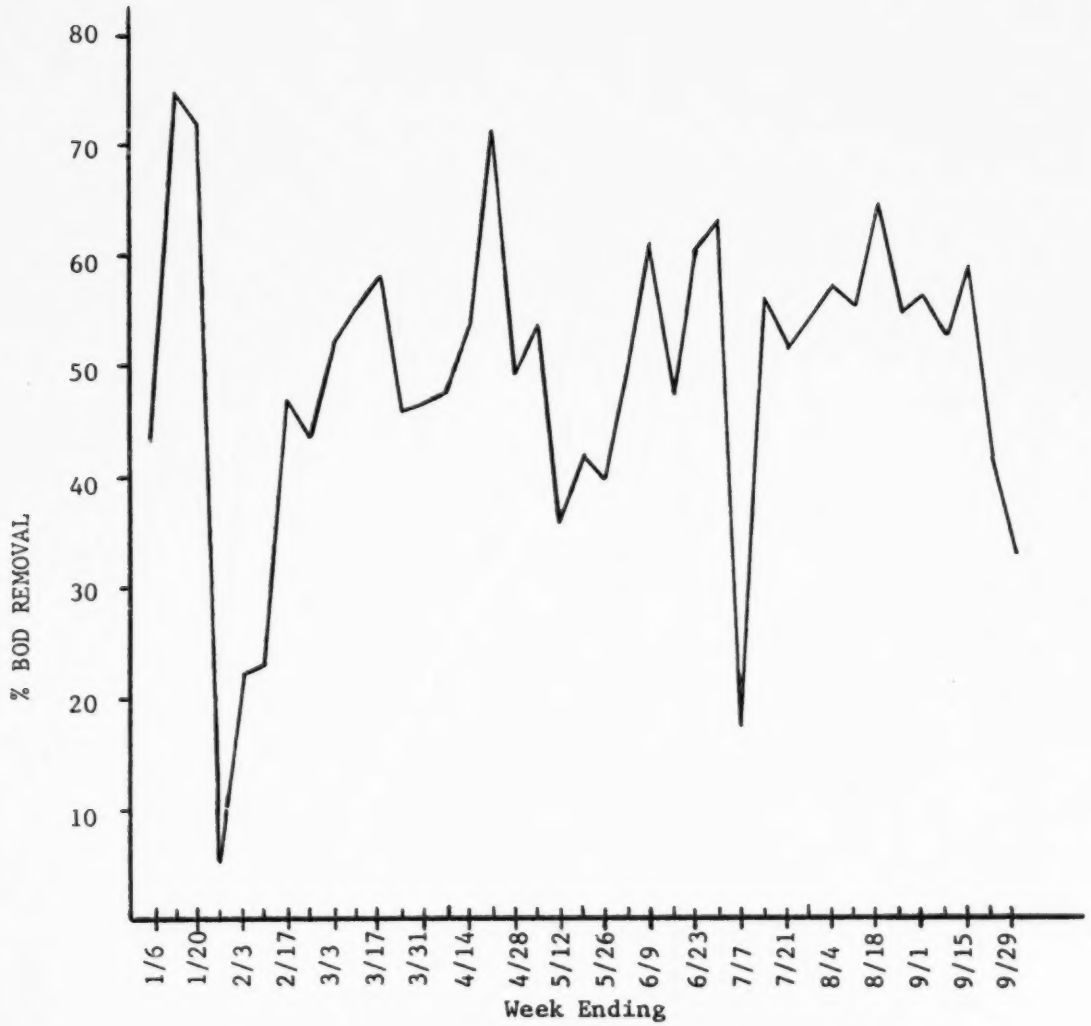


TABLE 6.7

MONTHLY AVERAGE PERFORMANCE SUMMARY FOR CARBON ADSORBERS

MONTH	TOC INFLUENT		PERCENT TOC REMOVED	BOD INFLUENT		PERCENT BOD REMOVED	HYDRAULIC FLUX	HYDRAULIC CONTACT TIME (MIN.)
	mg/l	lb/day	%	mg/l	lb/day	%	gpm/ft^2	
Jan.	83	412.6	41.5	11	57.1	43.3	5.22	28.0
Feb.	101	503.7	23.6	24	121.2	41.5	5.25	27.9
Mar.	93	469.1	45.9	23	118.0	51.6	5.35	27.4
Apr.	125	600.3	37.4	23	113.3	55.2	5.07	28.9
May	115	587.8	45.3	21	108.7	43.8	5.39	27.2
June	174	860.9	47.5	19	97.0	57.7	5.25	27.9
July	140	745.4	37.5	41	218.7	44.7	5.64	26.0
Aug.	150	754.6	41.3	49	249.6	57.4	5.34	27.6

FIGURE 6.9 INFLUENT AND EFFLUENT TOC SUMMARY FOR A COMPLETE 'FLIP-FLOP' CYCLE FOR #3 CARBON COLUMN

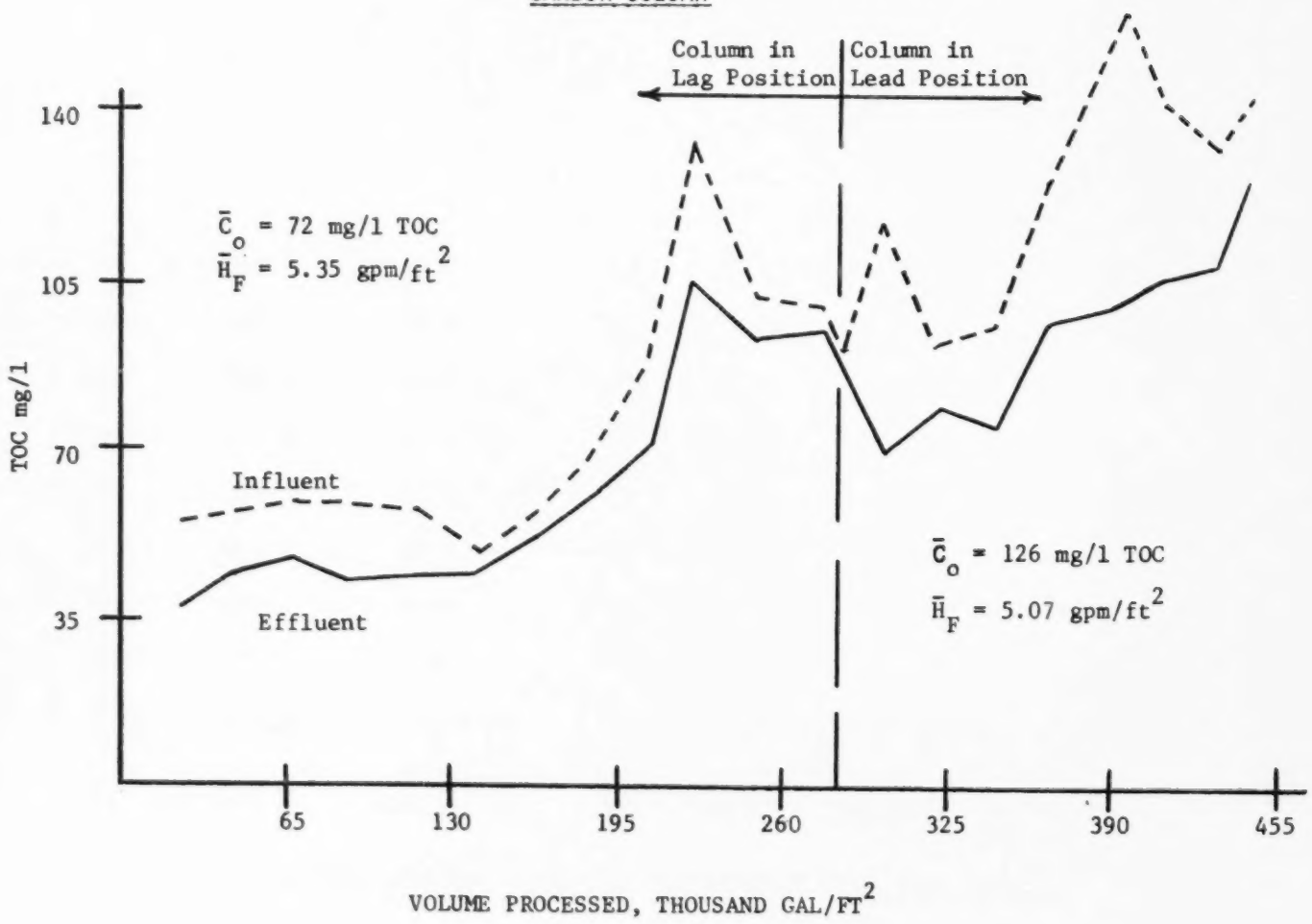


FIGURE 6.10 PERCENT TOC REMOVED PER VOLUME PROCESSED FOR A COMPLETE 'FLIP-FLOP' CYCLE FOR #3 CARBON COLUMN

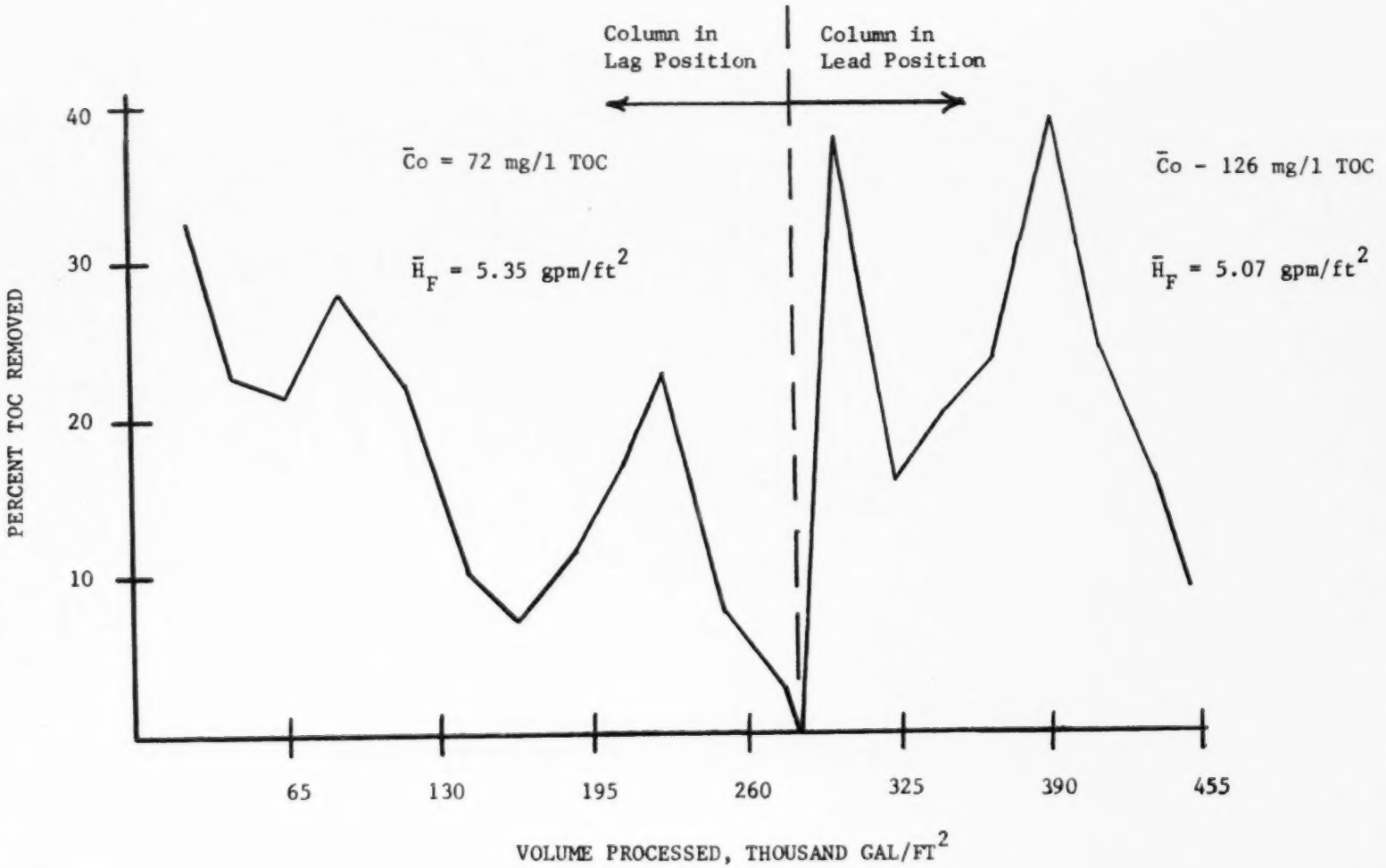
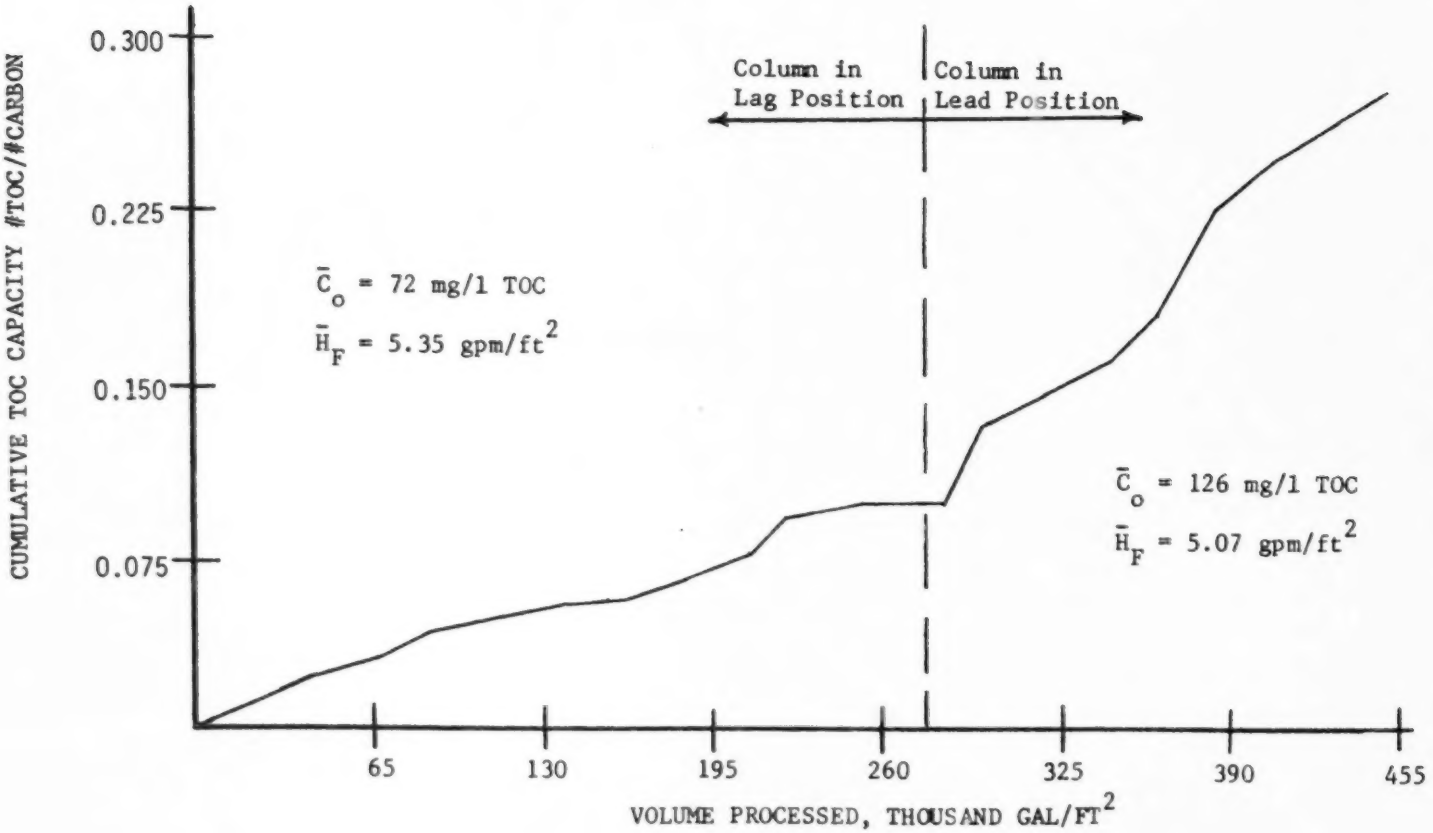


FIGURE 6.11 CUMULATIVE TOC CAPACITY FOR A COMPLETE 'FLIP-FLOP' CYCLE FOR #3 CARBON COLUMN



those previously noted over the evaluation period. Influent TOC concentrations to the fresh absorber in the lag position averaged 72.4 mg/l TOC; while influent TOC concentration averaged 126 mg/l in the lead position (see Figure 6.9). While in the lag position the maximum capacity reached was 0.0975 lb TOC/lb Carbon (Figure 6.11), which should have been relatively saturated with an equilibrium concentration of 100 to 105 mg/l TOC (Figure 6.9). It is believed that relative saturation was reached since the percent removal at the end of this lag cycle (see Figure 6.10) approached zero.

An ultimate capacity of 0.285 lb TOC/lb Carbon (Figure 6.11) was reached by the end of the lead cycle while an average TOC concentration of 126 mg/l. was applied to the absorber. By the time this capacity was reached, the percent TOC removal dropped to less than 10 percent. This indicates that most of the ultimate capacity was obtained for the equilbrium condition of 123 to 140 mg/l TOC concentration applied in the absorber feed. The ultimate capacity records of .285 lb TOC/lb Carbon approached that obtained during the overall test period, 0.333 lb TOC/lb Carbon as calculated by monthly TOC removal and carbon inventory.

Since the absorber influent TOC concentrations have been 3.6 fold larger than those expected in the design absorber, capacity expressed as the mass of TOC removed per mass of activated carbon should also be larger (i.e., the activated carbon should be more efficiently utilized since it should be in equilibrium with higher concentrations of influent TOC at exhaustion). The average accumulative mass of TOC removed over the 8-month period between January and August 1979 was 59,891 lbs. TOC. Over this time period, nine (9) recharges of carbon at approximately 20,000 lbs. each were used. Therefore, the TOC capacity of spent carbon onver the 8-month period was 0.333 lbs. TOC/lb carbon. As noted, this value is larger than that expected, 0.087 lbs. TOC/lb. carbon, when the influent equilibrium TOC concentration was anticipated to be only 33 mg/l TOC. If, however, the absorber has been coated with polymeric materials as previously postulated in Section VI.4.1, the increased equilibrium organic level appears to be more significant in raising the ultimate capacity than any inhibitory effects due to polyester or PVA, coating and/or blinding.

As previously noted, during mid-August significant anaerobic odors were observed emanating from the carbon adsorbtion vessels. Prior to this, carbon columns were backwashed at a frequency of approximately once every 48 hours. These odors were caused by organic growth within the adsorber vessel and believed to be stimulated by previous secondary system solids breakthrough across the filters during single media anthrafilt trial as previously discussed. During this period adsorbers were backwashed more frequently at approximately once per 24 hours. After sand filter media was replaced, no major odor problems have been encountered with carbon backwash frequency reduced to once every 48 hours.

In summary, the adsorbers have performed as good as can be expected. High effluent TOC and BOD levels have been due to high organic and hydraulic flux loadings which in turn are related to secondary system performance.

VI.5 HYDRAULIC EFFECTS OF ADVANCED WASTE TREATMENT UPON PRIMARY AND SECONDARY TREATMENT SYSTEMS OPERATION

As previously indicated in Section IV.4.2, VI 4.1, VI.2, VI.2., VI.4.1, and VI.4.2, the advanced waste water treatment system generates wastes in the form of sand filter and carbon adsorber backwash waters which, in the final design, are returned to the primary and secondary and AWT systems via the mudwell and/or off-specification basins (see Figure 6.1). In addition, much of the forward process flow rate to the sand filter is by-passed to the mudwell during the sand filter backwash period. This by-passed flow also appears in the return flow to the primary system. These return AWT waste flows appear in Table 6.8, and are continuous monthly averages for each return source. The main monthly raw waste water flow rates and the corresponding monthly standard deviations also appear in Table 6.8. The average total processed monthly flow rates, when the carbon adsorber is backwashed at frequencies of every other day and once perday, are also included in the table. As illustrated in the tabulation, the combined AWT recycle waste flows produced between 18.9 percent and 42.9 percent higher flow rates to all treatment systems, depending upon carbon adsorber backwash frequency, than the existing raw process waste flow rate. It is noted that the final design (see Figure 6.1) allowed for an average AWT waste return flow of 68 gpm with a raw waste water flow of 259 gpm, or a 26.3% increase in processed flow rate over the raw waste water base flow. Thus, the total processed flow, the summation of raw manufacturing, and AWT return wastes, was anticipated to be 327 gpm, a flow rate which should have been treatable by the existing primary and secondary system as previously discussed in Section VI.2.

The average raw manufacturing waste flow, anticipated to be 259 gpm with design modifications, ranged between 296 and 370 gpm, indicating 100 gpm more fresh water usage as previously discussed in Section VI.3.6. As the raw waste flow rate increases, the AWT backwash flow rate should also increase through increased backwash needs of the AWT system. The effect of the combination of these larger flows not only places a hydraulic burden upon the AWT system, but also a severe hydraulic burden upon the existing primary and secondary system. The average processed flows through the primary and secondary system presented in Table 6.7 ranged between 393 and 457 gpm with an average of 413 gpm. These flows are between 66 and 130 gpm larger than the expected design flow of 327 gpm. The hydraulic overload effects upon decreased hydraulic residence periods for any primary, secondary, or AWT systems can be formulated as:

TABLE 6.8

HYDRAULIC EFFECTS OF AWT SYSTEM WASTES ON PRIMARY AND SECONDARY PROCESS FLOW RATE

MONTH	RAW WASTE WATER FLOW		AVERAGE SAND FILTER BW & SECONDARY BY PASS gpm			AVERAGE CARBON ADSORBER BW FLOW gpm		AVERAGE PROCESS FLOW gpm		AVERAGE PERCENT INCREASE IN PROCESSED FLOW BY AWT WASTES	
	Q gpm	σ_Q gpm	BW	By Pass	Total	One AC BW/day	One AC BW/2 day	One AC BW/Day	One AC BW/2 Day	% Max.	% Min.
Jan.	329	47	32	16	48	33	16	410	393	24.6	19.4
Feb.	318	75	35	26	61	33	16	412	395	29.6	24.2
Mar.	331	58	38	18	56	33	16	420	403	26.8	21.8
Apr.	296	67	47	22	69	33	16	398	381	34.4	28.7
May	296	62	64	30	94	33	16	423	406	42.9	37.1
June	295	69	58	26	84	33	16	412	395	39.6	33.9
July	317	62	63	30	93	33	16	443	426	39.7	34.3
Aug.	370	89	34	20	54	33	16	457	440	23.5	18.9

$$\frac{\Theta \text{ Existing}}{\Theta \text{ Design}} = \frac{\forall/Q \text{ Existing}}{\forall/Q \text{ Design}} = \frac{Q \text{ Design}}{Q \text{ Existing}} ;$$

where: Θ = hydraulic residence period of a unit ($\forall/Q$) ;

% reduction in hydraulic residence period = $\frac{\Theta \text{ Design} - \Theta \text{ Existing}}{\Theta \text{ Design}} \times 100\%$

$$= \frac{1 - Q \text{ Design}}{Q \text{ Existing}} \times 100\%.$$

The minimum, maximum and mean reductions in hydraulic residence periods in all primary, secondary, and AWT systems, based upon the excess flow rates and the above relationships were 16.8, 28.4, and 20.80 percent, respectively. It is obvious that such reductions in residence periods will produce the following conditions in primary and secondary systems:

1. Primary System

   a) Lower suspended solids and organic removal efficiency which will produce organic overloads on secondary system, through hydraulic carryover.

2. Secondary System

   a) Biological Process
      i) organic overload carryover from primary system,
      ii) decreased organic removal efficiency due to reduced residence periods and organic overloads.

   b) Secondary Settling
      i) decreased suspended solids removal efficiency producing increased suspended solids carryover to AWT systems.

The net effects to the AWT system are: 1) increased suspended solids flux upon the sand filter, as evidenced in Section VI.4.1; 2) increased organic loadings upon the activated carbon adsorbers, as evidenced in Section VI.4.2; and 3) increased hydraulic loadings on both filtration and adsorption systems.

The increased hydraulic and mass loadings upon AWT filtration increases backwash water requirements which: 1) create higher flow rates through the primary secondary and AWT systems; and 2) create larger demands of reclaimed water which decreases the available supply of reclaim water for manufacturing recycle. Thus: 1) the sand filter is the overall

system "bottleneck", having difficulty processing the total flow, let alone the extra flow of stored processed reclaim water to be used during summer months (see Figure 6.1); 2) excess fresh water is added at the distribution tank, to supply recycle demands, and adds unwanted volume to the entire system; and 3) additional reclaimed water which accumulates in the system and is stored in the storage basin, (see Figure 6.1), cannot be reused since it must first be processed through the AWT system before it can be supplied to the distribution tank. The end result is that water accumulates in the system and must be eventually discharged.

Over the winter months during the test period, the 1.5 million gallon storage basin has been routinely filled over a 3-week period which indicates a winter system hydraulic imbalance of approximately 50 gpm excess flow. The design winter imbalance was estimated at approximately 10 gpm excess flow, indicating that the basin storage would last for approximately 14-½ weeks.

VI.5.1 ORGANIC QUALITY OR RECYCLE SYSTEM - "REFRACTORY" BUILDUP

As previously noted, the hydraulic overloads to the secondary system produced lower organic removal efficiencies and higher than expected BOD and TOC levels in the secondary effluent, larger than expected BOD and TOC loadings upon the carbon adsorbers, and larger than expected BOD and TOC levels in the adsorber effluent, reclaim water, (see Section VI.4.2).

The adsorber effluent BOD level was expected to be zero and the TOC level was set at a maximum of 17 mg/1. The 17 mg/1 TOC described in the Preliminary Engineering Report (1) was thought to be "refractory". It is important to note that refractory TOC could have several definitions such as: 1) organic material that could never be adsorbable on activitation carbon under any conditions (an absolute or true refractory). or 2) organic material not removable in the flowing column process condition considering constant applied hydraulic flux, contact periods and/or column length and a given applied TOC concentration level (an apparent refractory). If definition (1) is used, then the refractory TOC level should rise in a completely closed system through evaporative concentration, similar to predictions made for inorganic constituents in the Preliminary Report (1) and presented in Table 4.6*. As such, the predicted net TOC input through city water and reclaimed wastewater would have been:

City water input + reclaimed wastewater input = Net Total Input

$$1440 \frac{M}{D} \quad \frac{1 \text{ MG}}{10^6 \text{ gal}} \quad \frac{8.34 \frac{\text{lb}}{\text{MG}}}{\text{mg/l}} \quad 73 \text{ gpm } (0 \text{ mg/l}) + (186 \text{ gpm}) (17 \text{mg/l})$$

$$= 38.0 \frac{\text{lb}}{\text{D}} \text{ TOC}$$

* assumes no further biochemical degredation within process coolings and waste treatment systems.

Since, the TOC input = drift losses for summer or winter conditions, the predicted design equilibrium TOC level of reclaim water calculated in the Preliminary Report (1) should have been:

$$W_{Summer} = \frac{23.1}{0.840} = 45.2 \text{ mg/l TOC refractory equilibrium}$$

$$W_{Winter} = \frac{23.1}{0.831} = 45.7 \text{ mg/l TOC refractory equilibrium}$$

rather than 17 mg/l.

If the expected refractory carbon level of 17 mg/l is defined as in Definition 2 above, the system equilibrium TOC could even be larger than the 45 mg/l TOC previously calculated. As adsorber effluent TOC, which is adsorbable, increases in the system through evaporation concentration, and the system hydraulic flux and contact periods remain constant, effluent TOC values should rise over the once through value of 17 mg/l TOC, which was the input value used in the above calculation. Thus, the TOC values measured in the adsorber effluent should have been at least 45 mg/l, even if all treatment systems were hydraulically loaded at design condition. It is no wonder that adsorber effluent TOC values approached a mean value of 73 mg/l TOC when all systems were hydraulically overloaded.

Not only is it presently not known what fraction of the 73 mg/l TOC contained in the adsorber effluent is truly refractory, but also it is not known what fraction of the 17 mg/l TOC design level was truly refractory. This may be important since the concentration of these materials would surely build up in the system. Furthermore, it is not known at this time whether any of either the true or apparent refractory TOC material can cause or did cause any decrease in biological activity within the secondary activated sludge system during this study. Certainly the hydraulic and hydraulically promoted organic overloads to the secondary system are responsible for high BOD and TOC values in the secondary effluent. However, it is not known at this time whether or not the high BOD and TOC values recorded during the study were solely promoted by the hydraulic overloads or promoted by a combination of hydraulic overloads and reduced bio-activity resulting from refractory build up. The effect, if any, of refractory build up can only be evaluated if secondary system hydraulic overloading can be reduced and system closure is maintained for extended periods of time.

CHAPTER VII

PLANS FOR OVERALL SYSTEM IMPROVEMENT

VII.1. OVERALL SYSTEM NEEDS

In general, all flows of (1) raw waste water, (2) AWT recycle wastes, and (3) fresh water make-up must be reduced in order to achieve extended total system closure. If system closure is achieved, inorganic and organic dissolved solids may present problems. the scope of these potential problems cannot be accurately predicted until extended hydraulic closure of the system is achieved. The justification for these potential problems has been fully described in Sections IV and VI.5.1. It is certain that if the inorganic chemical coalgulants, $FeCl_3$ and bentonite clay as described in Appendix 2, were reduced and/or eliminated and emulsion breaking performance within the primary system maintained or bettered; the total dissolved solids level within recycle systems would be more favorable during extended system closure. Thus, the following plan for system improvement with optimistic system hydraulic closure has been either formulated and/or adopted.

VII.2. HYDRAULIC FLOW REDUCTION

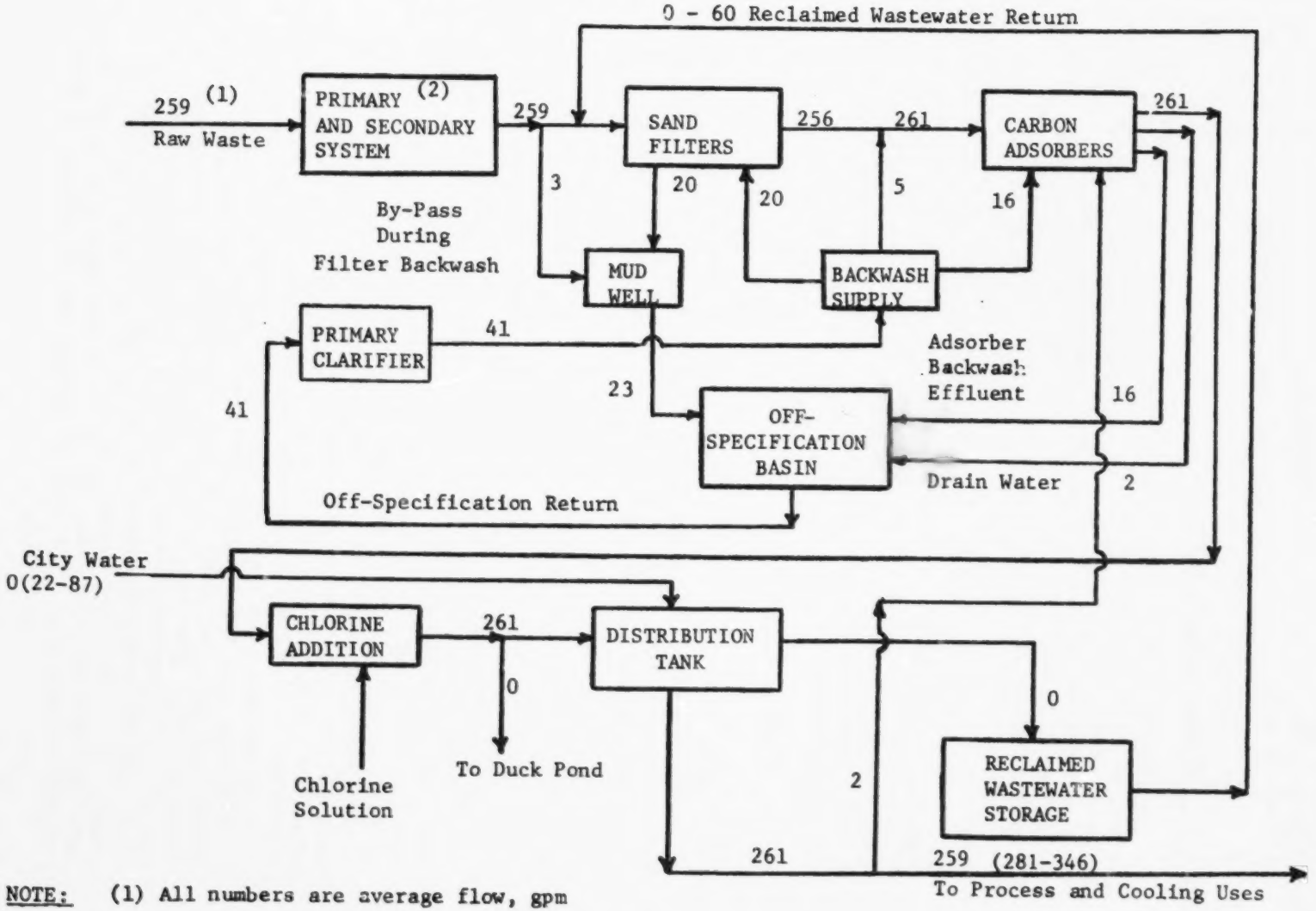
VII.2.1 RAW WASTEWATER REDUCTION

Maintenance, repair, and waste collection system modification, as described in Section VI.3.6 are presently underway to reduce extraneous raw wastewater and fresh water intrusion within the manufacturing plant.

VII.2.2 AWT RECYCLE WASTE REDUCTION

As presented earlier, AWT recycle waste reduction can be achieved through reduction of hydraulic and/or suspended solid loadings upon the AWT systems. This could be accomplished through treatment system modification as illustrated in Figure 7.1. The modification essentially involves isolating one of the five (5) parallel existing primary clarifiers from the raw waste flow and processing segregated AWT backwash recycle wastes through the isolated clarifier. To achieve necessary low suspended solids concentrations from the isolated clarifier, a separate, new and effective coagulant system may be developed. If effective suspended solids removal can be achieved and the raw waste flow can be effectively treated by the remaining clarifiers, then the isolated clarifier effluent could be directly reused for backwash water supply to the entire AWT system. Excess returned backwash water generated through secondary by-pass during sand filter backwash operations (see Section VI.1.1) could be diverted to the adsorber feed sump via a gravity overflow located at the backwash supply sump. This flow could range from 16 to 30 gpm (Table 6.7). It most probably would be even lower, since the magnitude is directly related to sand filter backwash frequency and the frequency would

FIGURE 7.1 PROPOSED WASTE TREATMENT SYSTEM DESIGN



NOTE: (1) All numbers are average flow, gpm

(2) Primary system includes four parellel clarifiers

be lower since the hydraulic and suspended solids loading upon the secondary and AWT systems would be reduced. Hydraulically, the overall modification would account for a flow reduction of 64 to 127 gpm to the secondary and AWT system process flow rate (Table 6.7). The modification would also increase the hydraulic residence periods in all processes within the secondary system by as much as 21% and AWT system by as much as 20% for the sand filter and 18% for the carbon adsorber (based upon design flows in Figures 6.1 and 7.1).

A pilot trial program is currently underway which involves: (1) clarifier isolation; (2) identification of coagulant systems to effectively remove suspended solids in both segregated AWT system backwash wastes and the segregated raw waste water flow; (3) the effects of the processed segregated flow upon AWT filter and adsorber backwashing operations, and (4) the effect of the hydraulic excess flow, created by secondary bypass during sand filter backwash, which is only treated by carbon adsorption, upon reclaim water quality.

The program involves the isolation of the clarifier and AWT recycle waste feed and evaluation of full-scale clarifier performance. Simultaneously, the performance of the remaining clarifiers with segregated raw waste will be evaluated. Upon successful evaluation of the isolated clarifier effluent, through bench scale tests, further full-scale trials will be undertaken. These trials will involve the full-scale segregation of the isolated clarifier effluent to the backwash supply sump, and full-scale backwash testing while the entire secondary and AWT system response is monitored with respect to hydraulic, organic, and inorganic parameters.

If this entire program proves successful, permanent piping for clarifier-backwash treatment segregation will be installed. Furthermore, the modification will certainly improve the recycle system. However, only total system operation over an extended time will provide data which will demonstrate that the modification produced an improvement approaching total recycle with zero discharge.

VII.3. RAW WASTE PRIMARY TREATMENT CHEMICAL COAGULANTS

Since the recycle system began operation, several time periods have existed when the chloride concentration of reclaim water rose to unusually high levels (500 to 600 mg/l Cl^-). Surely these concentrations would be even larger if the entire system was completely closed with no partial discharge. Large chloride concentrations are unwanted, since they can accelerate corrosion within cooling and process water system hardware. In addition to manufacturing chemical losses, chlorides are added to the wastewater through the use of the existing $FeCl_3$ - Bentonite Clay-anionic polymer primary treatment coagulant system (see Appendix B).

If a new primary coagulant system consisting of only polyelectrolytes was developed which, (1) destabilized emulsified chemicals contained in raw wastewater, equally or better than the $FeCl_3$ system, and (2) was cost effective; a distinct advantage with respect to minimizing chloride accumulation within the recycle system would be achieved. Additionally, such a coagulant system could possibly result in more compact primary suspended solids floc having larger terminal settling velocity which would allow a larger hydraulic flux upon the existing four primary system clarifiers (see Section VII.2.2). Presently, an apparently effective polyelectrolyte primary coagulant system has been developed, and pilot testing of this system is in progress. Results indicate that the performance of the polymer coagulants, are equal to or better than that of the $FeCl_3$ - bentonite-polymer system.

VII.4. FRESH WATER MAKEUP AT RECLAIM DISTRIBUTION TANK

When the recycle demand flow exceeds the AWT process flow, a demand surge, the supply volume in the reclaim distribution tank decreases. The entire cooling and process water needs of the plant are supplied by this system. If any of the waste treatment systems fail to an extent that reclaim water quality or hydraulic supply is unsatisfactory for the recycle demand, emergency fresh water must be supplied to the manufacturing plant. Currently, the emergency method available for use is an automatic/manual fresh water makeup system located at the reclaim distribution tank. Thus, if the distribution tank does not contain water, the entire manufacturing facility will not have a water supply. The automatic fresh water makeup system can supply 200 to 350 gpm of fresh water to the distribution tank through an automatically controlled line. Much of the time over the test period either the reclaim demand has been so large or the reclaim supply so small (i.e., due to AWT "bottleneck" problems outlined in Section VI.5.), that this fresh water supply was not large enough. Thus, a manually operated 4-inch fresh water supply line was installed to meet periodic reclaim supply deficiencies. Furthermore, recycle system operators are under extreme psychological pressure to maintain an adequate supply level within the reclaim distribution tank since it is the only cooling and process water source for the entire manufacturing facility. Thus, the net result is that excess fresh water is often manually added to the distribution tank to avoid potential supply deficiencies and alleviate operator worry.

In the near future, this entire makeup system will be studied to define improvements which alleviate these conditions. Such improvements could include: conversion of the four-inch supply line to automatic control; lowering the low level automatic set point to increase surge capacity of the distribution tank, and installation of new flow meters on the entire makeup system.

VIII. REFERENCES

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2. Angelbeck, D.I., Reed, W., and Thomas, S.H., "Closed Loop Recycle System for Fiberglass Insulation Manufactive", Proceedings of the 26th Purdue Industrial Waste Conference, Purdue University, (1971).

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4. West, A.W., "Plant Performance at the Owens-Corning Fiberglas Corporation Wastewater Treatment Facility, Anderson, South Carolina", prepared by EPA National Field Investigation Center, (1973).

5. Pharis, P., and Monaghan, G., "Biological Treatment of Textile and Sanitary Wastes from a Fiberglas Plant", Journal Water Pollution Control Federation, (1965).

6. "Standard Methods for the Examination of Water and Wastewater", 14th Edition, American Public Health Association, Washington, D.C., (1976).

APPENDIX A

ESTIMATION OF TOTAL DISSOLVED SOLIDS LOST IN PARTIAL DISCHARGE

Given Information:

Quantity	Description	Reference or Source
86 gpm	Average corrected discharge	Section IV.4
73 gpm	Planned fresh water input to existing system	Figure 4.2
97 gpm	Unplanned fresh water input to existing system	Figure 4.2
300 gpm	Average flow of once through system 1/76 through 6/76	Table 5.1
52 mg/1 TDS	Average TDS concentration of fresh water	(2)
280 mg/1 TDS	Average TDS concentration of AWT effluent in once through system 1/76 through 6/76	(2)
510 mg/1 TDS	Average TDS concentration of reclaimed wastewater 1/79 through 9/79	Table 4.6
0.835 (W)	Average mass loss rate lb/day through drift in total recycle system, if cooling system operation was as planned. (W) is concentration of parameter in reclaim supply (mg/1)	(2)

Rate of expected TDS input = (input through fresh) + (input through manufacture and net treatment effects)* = $\frac{(73 + 97)\ (52)\ (1440)\ (8.34)}{10^6}$ + $\frac{(300 - 73)\ (280 - 52)\ (1440)\ (8.34)}{10^6}$ = 106 + 622 = 728 lb/day

Rate of loss through partial discharge* = $\frac{86\ (510)\ (8.34)\ (1440)}{10^6}$ = 527 lb/day

*Treatment system using $FeCl_3$, clay, and cationic polymer

Necessary drift loss rate for equilibrium* = 728 lb/day - 527 lb/day

= 201 lb/day

Expected drift loss rate for equilibrium* = 0.835W = 0.835 (510)

= 425 lb/day

Necessary rate (201 lb/day) < Expected rate (425 lb/day)

Thus, system with partial discharge is loosing more than enough solids.

*Treatment system using $FeCl_3$, clay, and cationic polymer

APPENDIX B

EXCERPTS FROM PRIMARY AND SECONDARY OPERATIONS MANUAL

A. SURGE TANKS

1. DESCRIPTION

The purpose of the surge tanks is to store chemical dumps from the chemical plant and meter them on a controlled basis into the waste treatment plant. There are three surge tanks (see Figure 1A). Two of these tanks hold 25,000 gallons while the other holds 10,000 gallons. Each tank has an inlet and outlet for the wastewater; an inlet for acid and an inlet for caustic in case it is necessary to adjust the pH in the surge tanks, an inlet for mixing air; and a scale on the side of the tank showing the liquid height inside the tank. There is a by-pass line through which the wastewater can be put directly into the plant without going through the tanks. Also, there is a pump placed on the inlet side of the tanks that would allow a tank truck to hook up and pump directly into or out of the tanks.

2. NORMAL OPERATION

The wastewater (Figure 2A), as it comes from the chemical plant is collected in one of the tanks. When the tank is full, the wastewater is manually diverted into another tank. A high level overflow between tanks prevents them from overflowing. A sample is collected from the full tank and analyzed for total organic carbon.

The small surge tank (capacity 10,000 gal.) is reserved for an unusually concentrated waste which sometimes comes from the chemical plant. The high TOC on this water dictates a very slow release into the system. The chemical plant operator has been instructed to inform the treatment plant operator of this kind of dump. The treatment plant operator should then divert the waste to the small tank. When he is certain all the waste has been collected, the operator switches back to the previously used tank and determines the release rate for the small tank.

Under normal conditions, the tanks fill slowly and there is plenty of time to dump one tank before the other. There are certain times when one tank is down or when heavy rains or wash-down cause excessive flows. If there is not a place to put additional water, the operator will have to drain the tanks. However, the TOC of the tanks should be logged and the cause of the excessive flows should be identified. The tank with the lowest TOC should be drained first.

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Figure 1A

WASTEWATER TREATMENT PLANT SCHEMATIC

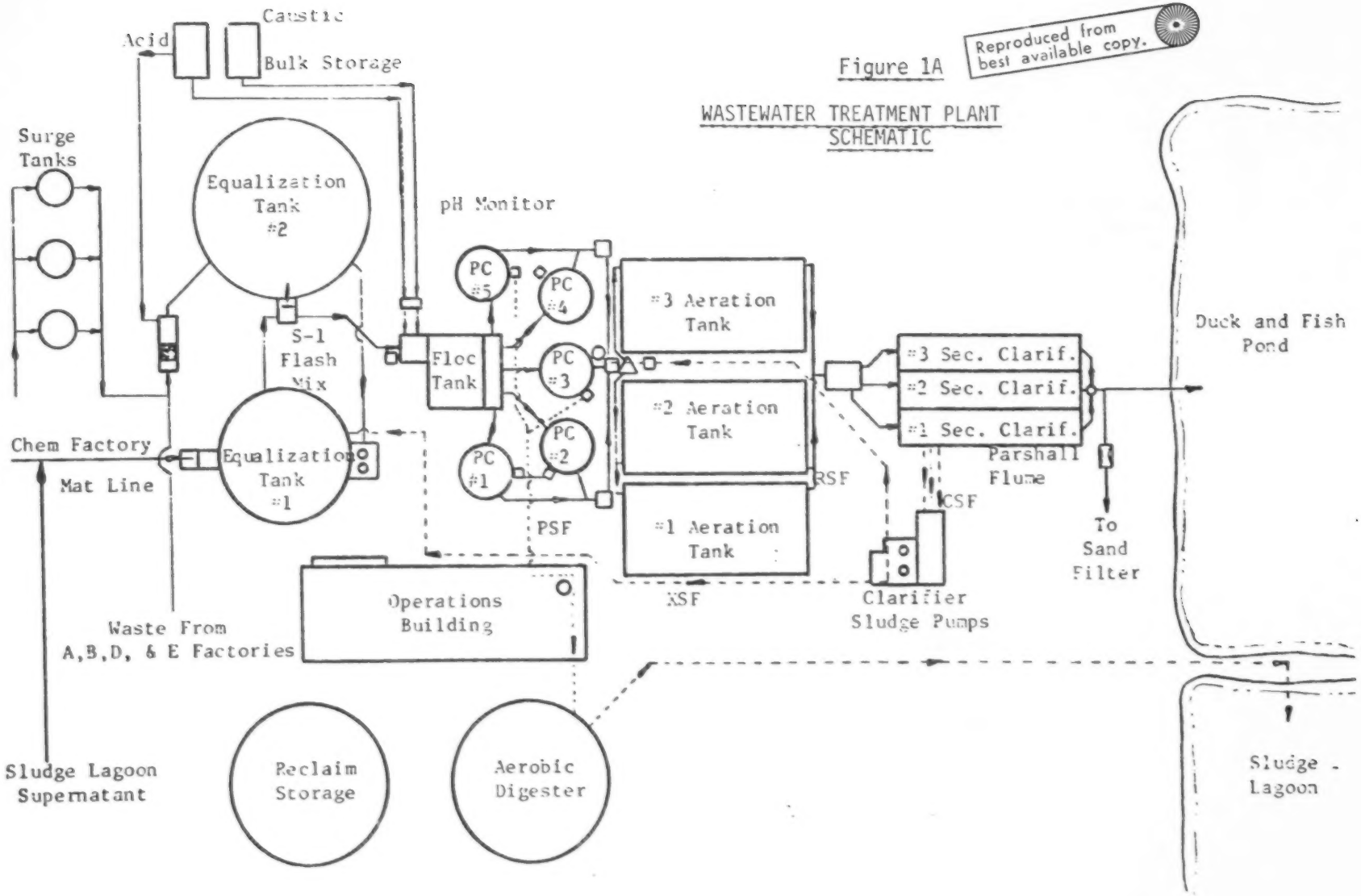
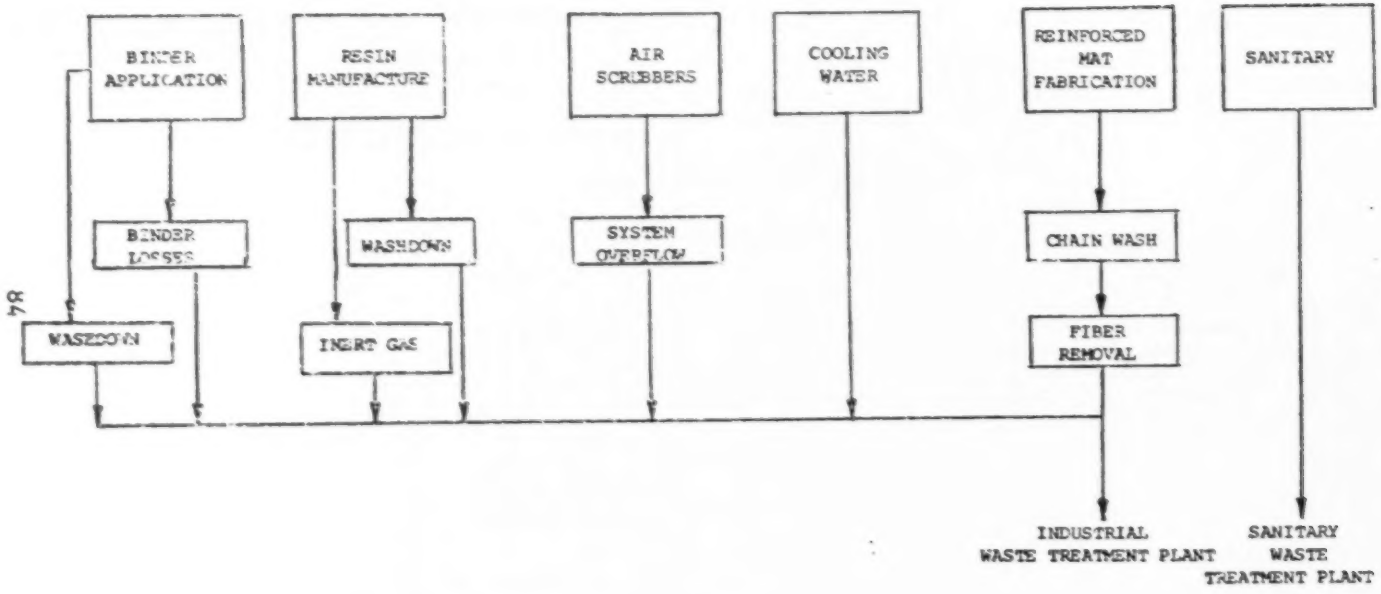


FIGURE 2A

EXISTING WASTEWATER SOURCES

SOURCES OF WASTEWATER FROM THE ANDERSON PLANT



3. POTENTIAL PROBLEMS

During power failures, feed to the surge tanks will be shut down. However, the tanks will continue to drain. If a power failure of longer than 30 minutes occurs, the drain valve should be closed.

Feed from the surge tanks should be completely shut off if the main plant is in an upset condition or experiencing high TOC's from some other area. Adjustments to the feed rate should be noted in the plant operating log.

B. EQUALIZATION BASINS

1. DESCRIPTION

There are two equalization basins. Basin No. 1 is 34 ft. in diameter and 15 ft. deep while Basin No. 2 is 50 ft. in diameter and 17 ft. deep. There are two direct coupled, centrifugal pumps having capacity of 950 gallons per minute each that pump water from Basin No. 2 to Basin No.1. Both basins have diffused air which provides the mixing action. The two basins are connected by a distribution box.

2. NORMAL OPERATION

The two equalization basins serve to throughly mix the waste so that any shock to the plant will be somewhat diluted. Basin No. 1 is fed by a line that comes from the matline, the off-spec pond, the sludge lagoon. Basin No. 2 is fed by wastewater from Factories A, D and E. Drain lines from the chemical plant surge tanks also enter this basin.

The wastewater from Basin No. 2 is constantly being pumped into Basin No. 1 by one of the two pumps described earlier. The overflow from Basin No. 1 goes through a valve to the distribution box. From the distribution box, part of the flow goes into the flash mixer while the rest goes back into Basin No.2. The amount of flow going either way is controlled by a sluice gate in the distribution box. Also in this distribution box there are two pipes for chemical addition. These chemicals act as coagulants so that most of the suspended and colloidal solids can be removed in the primary clarifiers.

3. POTENTIAL PROBLEMS

The equalization basins require very little operator attention. Some of the problems experienced in the past include:

b. COAGULANTS. The Anderson plant uses ferric chloride $FeCl_3$, Bentonite Clay and an anionic polymer.[1] The required concentration of each chemical is best determined by a jar test.

The required concentration can then be converted to the proper pump flow rate.

3. POTENTIAL PROBLEMS

In addition to mechanical or electrical failure of the flash mix or flocculator drive motor, the major problem involves the coagulation process itself. If the primary clarifiers become cloudy, the coagulant aids have become ineffective and a jar test should be run to determine new concentrations.

The flash mixer shaft can occasionally become entangled with glass or rags. When this happens, the mixer should be stopped and the shaft cleaned. If the shaft is badly entangled, the flash mix tank can be drained by shutting off forward flow and closing the sluice gate between the flash mix and equalization basins.

D. PRIMARY CLARIFIERS

1. DESCRIPTION

From the flocculation tanks waste flows through five telescopic valves to five primary clarifiers, when the suspended and coagulated solids are removed from the wastewater by gravity. The clarifiers are of the rimflow design where wastewater enters the tank tangentially, flows under a skirt and the supernatant overflows a weir in the center. Each clarifier is 14 feet in diameter. Sludge is withdrawn through a telescopic valve into a sludge well.

2. NORMAL OPERATION

The clarifier mechanism will rotate continuously through the bottom of each clarifier, pushing solids to the centerwell and preventing excessive compaction.

3. POTENTIAL PROBLEMS

There are three potential problems with the clarifier operation. First, an obstruction in the clarifier can block the rotation of the mechanism. This will cause a shear pin to break, which in turn disconnects the gears of the dirve. The motor will continue to operate, but the mechanism will not rotate. Before the shear pin is replaced, the clarifier should

[1]May be replaced with total polyelectrolyte system.

be pumped down to find the cause of failure.

The second problem involves sludge withdrawal itself. It is possible that a "hole" can be pulled in the sludge blanket and clear water will be drained into the sludge well. When this happens, it is necessary to break up the sludge blanket with an air line.

The third potential problem is the most common. If the coagulation system fails, carryover from the clarifier will be very turbid. This problem is usually associated with the chemical feed system upstream. However, if there are discrete particles in the clarifier overflow, it indicate the sludge blanket is too high and solids are being swept from the blanket surface.

E. ACTIVITATED SLUDGE SYSTEM

1. DESCRIPTION

The heart of the Anderson treatment plant is the activated sludge system. Physical components of the process include three 140,000 gallon aeration basins, three 10 x 50 rectangular clarifiers, two return sludge pumps, one waste sludge pump, one forward flow pump, ferric chloride and polyelectrolyte chemical feed systems, and positive displacement blowers. The combined purpose of these units is to biologically remove soluble and colloidal organics from the wastewater. The operator should be familiar with basic terminology and concepts of activated sludge.

Figure 1A shows the basic process schematic of the activated sludge system. From the aeration basins, waste flows into a splitter box and then into three final clarifiers. A coagulant aid (ferric chloride or polyelectrolyte) is added to the splitter box. Sludge is drawn from the clarifiers through three telescopic valves to a sump pump where the recycle sludge pumps return sludge to the front of the aeration basins. When required, liquid fertilizer is added to the recycle sludge pump pit. Effluent from the clarifiers flows by gravity through a parshall flume to the sand filters.

2. PROCESS

To produce an acceptable effluent, a biologically active sludge system must meet the following requirements:

a. There must be an adequate number of microorganisms exposed to the food source for sufficient time.

b. The aeration basin environment must be acceptable

to the organisms.

c. The sludge solids must readily separate from the treated wastewater in the clarifier.

3. NORMAL OPERATION

Control of an activated sludge system that is treating a complex industrial waste is difficult under the best circumstances. It is the operator's responsibility to maintain a proper environment for the system and to collect accurate data for subsequent process modifications.

The major monitoring is done once/day during what is called the "Operational Control Tests". The results of these tests are summarized on the chart shown in Figure 3A. The following summarizes the purpose of each test.

a. Flows. The operator first records the daily flows.

AFI Aerator Flow In

RSF Recycle Sludge Flow

WSF Waste Sludge Flow

b. Settleometer. The sludge settling rate is monitored in a Mallory Settleometer. This calibrated two liter beaker is filled with mixed liquor from the splitter box. The mixed liquor will form a blanket as it settles and the blanket is read at 5, 15 and 30 minutes.

c. Centrifuge. The solids level and the compaction tendency are monitored with a spin test. Samples from each aeration basin and the recycle sludge line are poured into an API tube and centrifuged. The percent solids are recorded on the sheet. This test is used primarily for balancing solids in each aeration basin and historical reference.

d. Sludge Blanket Depth. A sludge blanket finder is used for monitoring the blanket level in the final clarifier. The blanket should never be higher than five (5) feet from the water surface.

e. Turbidity. The efficiency of the solids removal in the final clarifier is gauged by the turbidity test. This test is quickly performed using a laboratory turbidimeter.

f. Aeration Tank DO. Dissolved oxygen is essential for the proper function of aerobic organisms. However, too much

FIGURE 3A OPERATIONAL CONTROL TESTS

Day_____
Date_____

Flows GPM	AFI_____ RSF_____ WSF_____		AFI_____ RSF_____ WSF_____		AFI_____ RSF_____ WSF_____	
	SST	SST	SSC	SSV	SSO	SSV	SSO
SETTLEOMETER	5						
	15						
	30						
	45						
	60						
Bine Time		Hrs.		Hrs.		Hrs.	
CENTRIFUGE		ATC #1_____ ATC #2_____ ATC #3_____ ATC Comb._____		ATC #1_____ ATC #2_____ ATC #3_____ ATC Comb._____		ATC #1_____ ATC #2_____ ATC #3_____ ATC Comb._____	
		RSC #1_____ RSC #2_____ RSC #3_____ RSC Comb._____		RSC #1_____ RSC #2_____ RSC #3_____ RSC Comb._____		RSC #1_____ RSC #2_____ RSC #3_____ RSC Comb._____	
Sludge Blanket Depth		DOB_____		DOB_____		DOB_____	
Turbidity Meter		Init._____ 1 Hr._____		Init._____ 1 Hr._____		Init._____ 1 Hr._____	
Temperature							
Pond DO							
Flow Adjustments							

DO wastes energy and causes excessive shear on the sludge mass. In a balanced, properly operated system, the DO should range from 1.0 to 3.0 mg/l. If the DO is above this level, it indicates the amount of food is low or the organisms have been shocked and available food is not being metabolized. If the DO is below 1.0 mg/l, the system is experiencing a high growth rate and filamentious organisms and poor settling may result.

g. pH. The activated sludge process will best perform at a pH range of 7.0 to 8.0. Acceptable performance can be achieved in a range of 6.0 to 9.0. The operator should be aware that carbon dioxide is a biological by-product of metabolism and forms carbonic acid in water. The incoming waste should be at least 7.0 to insure the aeration basin effluent is well above 6.0.

h. Temperature. All biological processes are temperature dependent. A decrease of 10°C will cut the biological activity approximately in half. It is important that aeration basin temperature be monitored in the fall and winter.

In addition to the operational control tests, operators should be vigilant for conditions which could affect the activated sludge environment. Conditions which signal potential upset include:

a. Increased Flow. Flows in excess of 600 gpm (.864 mgd) can cause problems in the clarifiers.

b. Increased TOC. TOC's in excess of certain limits can upset the activated sludge system. These limits will vary with time, season and the condition of the sludge mass.

c. Low or High DO. A sharp change in the dissolved oxygen level can indicate either an organic overload (low DO) or a shock load condition (high DO).

d. pH. The pH in the aeration basin should never get below 6.0 or above 9.0.

e. Foam. Excessive foaming can indicate a binder dump or an organic overload.

4. POTENTIAL PROBLEMS

The major problems with activated sludge systems concerns separating the biological solids in the secondary clarifier.

There are three adjustments that can be made when this problem occurs.

a. Chemical Dosage. The most common adjustment is to change the concentration of coagulant aids. This can best be determined with a jar test.

b. Sludge Recycle Rate. The sludge recycle rate can be adjusted by valving the discharge.

c. Sludge Age. The basic control parameter on the secondary system is the sludge age. This procedure is based on the length of time the average microorganism remains in the system. The age directly relates to the amount of excess sludge produced and to the settling characteristics of the cell mass. Sludge age can be calculated on the Anderson system as follows:

$$\text{Sludge Age} = \frac{\text{Vol. of Sludge in Basin}}{\text{Vol. of Sludge Wasted/day}}$$

This calculation assumes sludge is wasted from the aerator. If sludge is wasted from the returned sludge line, the following calculation should be used:

$$\text{Sludge Age} = \frac{\text{MLSS (mg/l) x .42}}{\text{RAS (mg/l x Vol Wasted/Day}}$$

5. REFERENCES

Additional information on the activated sludge process can be found in the following references:

a. Operational Control Procedures for the Activated Sludge Process, U.S. EPA, Office of Enforcement and General Counsel, 1973.

Part 1 Observations

Part 2 Control Tests

Appendix

b. Operation of Wastewater Treatment Plant, Manual of Practice No. 11, Published by the Water Pollution Control Federation, 1976.

c. Operator's Pocket Guide to Activated Sludge,

Part 1 The Basics

Part 2 Process Control and Trouble Shooting, Prepared by Stevens, Thomas & Runyan.

d. Wastewater Engineering, Ed. by Metcalfe and Eddy, Inc., McGraw Hill, 1979.

F. SLUDGE SYSTEM

1. DESCRIPTION

The sludge system consists of a 300,000 gallon aerobic digester and a two acre sludge lagoon. The digester was originally an anaerobic digester from which the floating cover was removed. The digester is 45 feet in diameter, 20 foot sidewall and a 5 foot deep conical bottom. The digester can be filled to within 2 feet of the top and has a usable capacity of 234,000 gallons. Supernatant from the sludge lagoon is pumped back to the equalization basin.

2. NORMAL OPERATION

The digester is drained by gravity about once a week on the average. The daily input averages 24,000 gallons. The digester removes organic matter similar to the activated sludge system.

Solids that carry through the digester will collect in the sludge pond. The sludge pond is a "facultative" process. This means that biological activity in the upper pond layers is aerobic, while the activity in the bottom is anaerobic. Maintenance of an aerobic layer is very important since it oxidizes hydrogen sulfide and minimizes the characteristic septic small of anaerobic processes.

3. POTENTIAL PROBLEMS

The digester is a biological system, similar to activated sludge and must produce an acceptable environment for the organisms to properly function. The major item that the operator can control is the oxygen input. He should insure that at least 1.0 mg/l O_2 is maintained in the tank.

Biological activity in the pond is temperature dependent and bio reactions will be much more rapid in water weather. The solids level in the pond will build over the winter, and as spring warms the pond up, the accumulated sludge layer will undergo rapid anaerobic degradation. Vigorous bubbling can be seen and sludge masses will often float. The greater risk of sludge odors will occur at this time. The operator can minimize odors by:

a. Keeping the pond surface clear by removing floating sludge

b. Increasing digester retention time by daily drawoff of small quantities of sludge.

In extreme cases, odors can be reduced by spreading sludge accumulations to other parts of the pond with a dragline or using chemical disinfectants such as chlorine to hold down biological activity.

APPENDIX C

SPECIAL MICROBIAL PROCEDURES

In order to evaluate the public health aspects of the new water reuse and recycling system at the Anderson, South Carolina, Owens-Corning Fiberglas Plant, JTC Environmental Consultants, Inc., was asked to provide bacterial and viral analyses on water circulating through the plant. The virus sample was collected on April 17, 1978, and the bacterial sample was taken on April 26, 1978.

A. VIRUS CONCENTRATING PROCEDURE

The basic virus monitoring apparatus and procedure is similar to that set forth in Standard Methods for the Analysis of Water and Wastewater (6). A summary of the procedure followed by JTC and the specific filters used for the concentration steps are described here.

The virus concentrating apparatus without the filters in place was sterilized with chlorine solution containing 25 mg per liter of free chlorine. The solution was forced into the unit and maintained there for a 30 minute contact period. This solution was then rinsed from the virus concentrator by allowing the water to be tested to flow through the system until all traces of chlorine were dissipated. The system was then flushed of all water by using air pressure and allowing adequate time for the water to drain.

The filter cartridge holders were then dismantled and the fiberglas filters installed using aseptic technique. Fiberglas filters for adsorbing virus consisted of honeycomb filters, Model A-27, obtained from Commercial Filters Division, Carborundum Company and 0.45 m filters from Filterite Corporation. Prefiltering was not utilized because of the low level suspended solids in the water and the possibility of virus loss during prefiltering.

Virus adsorption was enchanced by pH adjustment to 3.5 and addition of aluminum chloride. Hydrochloric acid and aluminum chloride solution were added by means of a proportional dosing pump set to provide a pH of 3.5 during the test runs and a final aluminum chloride concentration of 0.0015 M. The virus concentrator was operating a flow rate between one and three gallons per minute and periodically checked for pH to assure a value of 3.5. When necessary the proportioning pump was adjusted to maintain pH.

A standard solution of thiosulfate was pumped into the system through the use of a second proportioning pump to provide neutralization of chlorine. The thiosulfate solution was previously prepared to neutralize 10 ppm of total chloride. Upon testing of the water discharge from the virus concentrator, a chlorine residual of approximately 0.1 ppm was found in the processed water. Higher feed rates of thiosulfate did not remove the chlorine residual as determined by the orthotolidine method. Laboratory investigations

indicated that the positive chlorine residual was a result of interferences from components in the wastewater when using the orthotolidine method and not chlorine. However, to insure chlorine removal the thiosulfate solution was prepared to neutralize 20 ppm of total chlorine.

A total water sample of 93.1 gallons was processed. After processing this volume, all water that had passed through the concentrator was drained from the unit and the elutant vessel containing glycine buffer at pH 11.5 was connected to the filter. Air pressure was used to force the elutant through the filters. It was collected and immediately adjusted to pH 7.0. The eluate was dosed with penicillin and fungizone and frozen in dry ice for shipping to the laboratory.

Field efficiency for virus detection was tested by processing 78 gallons of wastewater under conditions identical to those described above for the wastewater except for the addition of a stock solution of polio virus I, CHAT strain. A total of 253 ml of stock virus solution was added to a total of 4,780 ml of thiosulfate solution. This thiosulfate solution was added to the process water by a proportioning pump during the field efficiency run. After completion of the efficiency run the thiosulfate-virus solution was measured at 2,520 ml resulting in a net use of 126.7 ml of stock virus solution. A sample of stock virus solution was taken in the field, packed in dry ice and returned to the laboratory for assay to establish total number of virus units added to the process water during the efficiency run.

The elution procedure during the field efficiency run was identical to that described above for the test run.

1. Reconcentration Steps

The frozen eluates samples were thawed upon receipt at the laboratory and reconcentrated by precipitation with ferric chloride. The pH of each eluate was adjusted to 3.5. Ferric chloride was added to give a concentration of 10^{-3}M. The solutions were then flocculated for 20 minutes, allowed to settle for 1/2 hour and the supernanant discarded. After centrifugation the precipitate was suspended in heat-inactivated calf serum and adjusted to pH 7.5. This solution was mixed on a magnetic stirrer to provide virus release. Bacteria and suspended mater were then removed by centrifugation at 7,000 to 8,000 rpm for 15 minutes. The supernatant was withdrawn, dosed with antibiotics of penicillin and fungizone and frozen prior to assay on primary rhesus monkey kidney cells and HeLa cells. Both the wastewater test run as well as the field efficiency run were handled identical during this reconcentration procedure. The reconcentration provided a final volume of 36 ml for the test sample and 63 ml for the field efficiency run.

B. VIRUS ASSAY PROCEDURES

The waste sample and virus seed concentrates were tested using the plaque assay method of two cell cultures. Petri dishes of primary rhesus monkey kidney (PRMK) tissue culture and HeLa cell culture were rinsed with 37°C minimal essential media (MEM), inoculated with 0.4 ml of the waste sample or 0.2 ml of dilutions of the virus preparations, and rocked continuously at 37°C for 90 minutes to allow even distribution of the virus. The cultures were then overlaid with an agar medium and incubated at 37°C. Cultures were checked daily for plaque formation and overlaid a second time with an agar media containing neutral red when plaques were noted. Plawues ere counted after 24 hours additional incubation.

C. BACTERIAL TESTING PROCEDURES

1. Fecal Coliforms

Duplicate samples of 250 ml, 100 ml, and 10 ml were filtered through Millipore filters. The filter funnel was washed down after each sample with 10 - 20 ml of sterile distilled water. In addition to the 6 samples, duplicate control samples of 10 ml of sterile distilled water were filtered. The filters were placed on M-FC broth and incubated at 45°C for 48 hours.

2. Fecal Streptococcus

Duplicate samples were filtered in a manner identical to that used for the fecal coliforms (described above). The filters were placed on KF streptococcus agar and incubated at 35°C for 48 hours.

3. Total Count

Duplicate samples of 100, 10, and 1 ml were filtered on the Millipore filter apparatus. Between each sample the filter funnel was washed down with 10 - 20 ml sterile distilled water. In addition, duplicate control samples of 10 ml of sterile distilled water were filtered. The filters were placed on M-Standard Methods broth and incubated at 35°C for 48 hours. Counts of colonies were taken at 24 hours and again at 48 hours.

4. Staphylococcus

Duplicate samples were filtered in a manner identical to that used for fecal coliforms (see above). Duplicate control samples were also filtered as for fecal coliform determination. The filters were placed on Chapman-Stone Agar and incubated at 35°C for 48 hours.

5. Total Facultative Organisms

In order to determine the number of facultative organisms, approximately 40 ml of sample as bubbled with pure oxygen through a sterile, cotton-plugged pipet for two hours at room temperature. It was felt that the exposure to pure oxygen would kill any obligate anaerobes persent in this sample. Following aeration, four samples each of five ml and one ml were inoculated by a pour-plate method in nutrient agar. Two plates of each sample plus two uninoculated control plates were incubated aerobically at 35°C for 48 hours. The remaining two plates were incubated in an anaerobic condition at 35°C for 48 hours. Colonies appearing on the anaerobic plates were considered to be facultative anaerobes.

6. Obligate Anaerobic Bacteria

Samples of 5 ml and 1 ml were set up in triplicate or quadruplicate in nutrient agar by the pour-plate technique. One or two plates of each sample volume were incubated aerobically at 35°C for 48 hours. The remaining plates of each sample volume were incubated anaerobically at 35°C for 48 hours. In addition, one uninoculated control plate was incubated aerobically and one anaerobically in an identical manner to the inoculated plates.

D. EXAMPLE CALCULATIONS

1. Field Efficiency Calculations

Virus Stock Pumped through the Concentrator:

$$253 \text{ ml} \quad \frac{2520}{5033} = 126.7 \text{ ml}$$

Virus Concentration of Stock Virus Solutions as measured by:

a) PMK: 2.5×10^5 PFU/ml
times 126.7 ml = 3.168×10^7 PFU

b) HeLa: 3.03×10^2 PFU/ml
times 126.7 ml = 3.839×10^4 PFU

Virus Recovered in Field Efficiency Run as measured by:

a) PMK: 4.5×10^4 PFU/ml
times 63 ml of final sample = 2.835×10^6 PFU

b) HeLa: 3.26×10^2 PFU/ml
times 63 ml of final sample = 2.054×10^4 PFU

Recovery Efficiency:

a) PMK: $\frac{2.835 \times 10^6}{3.168 \times 10^7} \times 100 = 9\%$

b) HeLa: $\frac{2.054 \times 10^4}{3.839 \times 10^4} \times 100 = 53\%$